Central Great Plains Research Station
1998 Research Progress Report

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Mahdi Al-Kaisi - Water Mgmt.
Dennis Kaan - Ag & Bus. Econ.
Mike Koch - Entomology

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Manuel Rosales - Agronomy
Josh Saunders - Range
Mike Sucik - Soil

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CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for optimal utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation / preservation.

CENTRAL GREAT PLAINS RESEARCH STATION STAFF

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Ginger Allen
Carolyn Brandon
Linda Pieper
Lewellyn Bass

TECHNOLOGY TRANSFER - 1998

Central Plains Resources Management Research Unit

NRCS Soil Quality Team:

1. Provided training on taking soil quality measurements in the field to NRCS employees in 6 states of the Northern Plains Area.

2. Published two fact sheets: "Feeding the soil" and "Soil quality indicators for whole-farm management in the central Great Plains".

3. Designed a soil quality training course that is being taught to NRCS employees across the U.S.

ARS Staff:

1. Sponsored our annual Summer Field Day on June 18, 1998. Approximately 150 producers, agricultural business representatives, USDA-NRCS personnel, and CSU scientists attended.

2. Shared research results with USDA-NRCS by writing two fact sheets.

3. Served on the Board of Directors for the Colorado Conservation Tillage Association, and three scientists presented research results at their annual winter meeting.

4. Sponsored the Maximum Economic Yield (MEY) Club at Akron, where bi-monthly meetings are held each winter. Staff presented research data to producers.

5. Designed an integrated livestock-cropping systems study for the Eastern Colorado Range Station.

6. Hosted a tour for foreign visitors with West Texas University, explaining our cropping systems and research studies.

7. Hosted a tour of 40 producers from Australia, explaining semiarid cropping systems and soil chemical and physical changes as induced by minimum- and no-till systems.

8. Four scientists presented research data on sunflower production at the National Sunflower Association Winter Workshop, Sidney NE.

SUMMARY OF 1998 WEATHER

CENTRAL GREAT PLAINS RESEARCH STATION
AKRON, COLORADO

R. Wayne Shawcroft
Regional Extension Irrigation Agronomist (Retired)
Farm Service Representative, Citizens National Bank of Akron

The 1998 weather year was influenced extensively by the general "El Niño" year that prevailed throughout the West and Southwestern United States. Although we escaped the severe drought and heat waves of Texas and Oklahoma, and the severe storms and flooding of other areas, the 1998 weather was influenced by the modified conditions brought on by El Niño.

Locally, the El Niño condition brought on a very mild and warm winter. Other features of the year were the very dry spring and very erratic rainfall pattern during the normal "wet" season. Several months also had record cold days, as well as record warm days, within the same month. Probably the most significant, as far as new weather records were concerned, was the month of September. September 1998 set a new record as the hottest September in the 91-year record. New records for both the average monthly mean temperature and the average monthly maximum temperature were set in September. Some of this warm condition prevailed into November as well, when a new record high average monthly minimum temperature was set.

Overall, 1998 was the driest year since 1976 and one of only two years in the last twenty years with a rainfall total of less than 13 inches.

TEMPERATURES

Monthly mean, maximum, and minimum temperatures are shown in Tables 1, 2, and 3. January and February were both much warmer than usual. There were no below zero temperatures recorded in either month. The coldest temperature in January was two days of +2 deg. F readings on Jan. 12 and 13. Amazingly, the coldest reading in the month of February was only a +17 on Feb. 1. In fact, there were only five days in February when the minimum temperature was below 20 degrees. While the minimum temperatures in February were well above average, the maximum temperatures were only slightly above average. Cooler temperatures prevailed through March and April, with both months averaging below the long-term average mean temperature. Of special note was the fact that the only below zero temperature recorded for the winter of 1997-98 was on March 11 with a reading of –2 degrees F. April remained cooler throughout the month. May brought a return of warmer than average conditions, with significantly warmer than average maximum temperatures.

June brought cooler temperatures with an average minimum temperature about 4.6 degrees below the long-term average minimum. By the end of June a significant heat spell occurred with several days of consecutive 90+ temperatures. July temperatures were more normal for this time of year, with several 90+ stretches and three 100 degree plus days. However by the 24th of the month, temperatures moderated, and the remaining part of July, as well as the month of August were slightly cooler than average.

The month of September was the most significant month as far as departure from the normal or average conditions. New record high average mean and average maximum temperatures were set. The average minimum temperature ranked as the 4th warmest average minimum of the 91-

year record. Several single day records were also set in September, specifically new record maximums of 98,97,97 on the 5th,11th,26th respectively. October was considerably cooler, and brought the first freezing temperature of 28 degrees on the 6th. A new record low maximum of only 46 degrees was set on October 3rd. By the end of October a return to warm, mild conditions occurred, with a new record high minimum of 45 degrees being set on Oct. 28. Warm conditions prevailed through November, and a new 88-year record high average high minimum temperature of 29.40 degrees was set. Several new daily warm temperature records in the last part of November.

The warm, mild winter temperatures continued through the first half of December, but finally a more seasonal, winter-like cold snap occurred around Dec. 20, and several days of continuous below zero conditions prevailed. A new record low maximum temperature of 5 degrees was set on Dec. 20, and six consecutive below zero readings occurred from Dec. 20th to 25th, with a –19 degree reading as the coldest on Dec. 22. This was the first significant "more normal" cold temperature spell for several winters.

The average annual mean temperature for 1998 was 50.438 degrees which ranks as the 8th warmest year on record, and in the upper 10% of the warmest years of the 87-year record with records for the full year. This also puts 1998 as the only year since 1986 to rank in the warmest 10% of the years on record. The annual average temperature for 1998 and 1994 are the only years since 1986 to rank in the warmest 10% of the years. The 87-year average for the annual mean temperature at the Research Station is 48.496 degrees. (see graph of Annual Average Mean Temperatures)

A summary of the **Growing-Degree-Days** for the summer period is shown in Table 4. A graph of the cumulative GDD is also shown. The cumulative GDD shows that this index remained slightly above the long-term average for the summer period, with slight increases in late May, decreases in mid June, an increase in late July, and a significant increase in September. The ending summer total of 2738 GDD units was 109% above the 2511 average total for the May-Sept. period. In general, the temperature regime for summer crops was nearly ideal for crop growth and development. Most crops reached maturity at about the usual pace.

PRECIPITATION

The **annual total precipitation for 1998** was only **12.18 inches**, which ranks as the **81st wettest** or **11th driest** of the 91-year record. The May-Sept. period had a total of only 7.98 inches, which is significantly below the average for this period of 11.47 inches.

After a much wetter than average February, the March-April-May-June period was very dry. The 0.36 inch total for June ranked as the 4th driest June on record. July brought some significant thunderstorms around July 4th, 10th, and a rainy period on the 22nd – 26th. The early part of August provided the last significant rainfall of the summer period.

Some severe hail storms were scattered around the area. Some, that caused severe crop damage, occurred northeast of Akron on May 22 and again on June 22.

Snowfall in the Winter of 97-98 was very low, as shown in Table 4. Total snow depth for the Jan.-April 98 period was only 7.50 inches. The winter of 1998-99 brought only small snowstorms of 1.5 inches in early November, and a 4.5 inch-storm around Dec. 19-21.

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*The following tables and graphs show other features of the 1998 weather year, and compare the 1998 season with the long-term record. This completes the **91st year** of compilation of daily rainfall and temperature records at the Research Station.*

TABLE 1. AVERAGE MONTHLY MEAN TEMPERATURES

(Based on 8:00 am daily observation time) USDA-ARS RESEARCH STATION, AKRON, CO

MONTH	1998 AVERAGE	91-YEAR 1908-98 AVERAGE	DEPARTURE	HIGH AVERAGE	(YEAR)	LOW AVERAGE	(YEAR)
JAN	31.40 °F	25.14 °F	6.26 °F	35.4	(1986)	7.8	(1937)
FEB	34.93	29.88	5.04	41.1	(1954)	16.0	(1929)
MAR	36.24	36.34	-0.10	45.5	(1986)	19.9	(1912)
APR	44.68	46.44	-1.75	53.6	(1930)	35.9	(1920)
MAY	59.98	56.21	3.77	65.3	(1934)	48.0	(1995)
JUN	63.80	66.55	-2.75	73.5	(1956)	59.1	(1945)
JUL	74.66	73.29	1.37	79.9	(1934)	67.6	(1915)
AUG	71.40	71.45	-0.05	77.0	(1983)	65.3	(1927)
SEP	**68.42**	62.35	6.06	**68.42**	**(1998)**	53.8	(1965)
OCT	49.89	50.33	-0.44	59.0	(1963)	40.7	(1969)
NOV	41.35	36.64	4.71	45.8	(1949)	23.5	(1929)
DEC	28.50	27.53	0.97	36.3	(1980)	12.7	(1983)
YEARLY AVE MEAN TEMP	50.438 °F	48.514 °F	1.924 °F	52.64	(1934)	44.81	(1912)

ALL TEMPERATURES IN DEGREES F 1998 DATA INCLUDED IN AVERAGES

▭ =New Records

TABLE 2. AVERAGE MONTHLY MAXIMUM TEMPERATURES

JAN	45.26 °F	37.86 °F	7.40 °F	49.6	(1934)	20.8	(1937)
FEB	45.46	42.71	2.75	56.0	(1954)	28.6	(1929)
MAR	49.10	49.61	-0.51	60.6	(1972)	28.7	(1912)
APR	60.03	60.47	-0.44	69.9	(1908)	45.7	(1920)
MAY	76.39	69.99	6.40	81.9	(1934)	57.5	(1995)
JUN	80.30	81.28	-0.98	89.6	(1952)	70.0	(1928)
JUL	88.90	88.70	0.20	97.6	(1934)	81.2	(1915)
AUG	86.90	86.81	0.09	93.8	(1937)	77.5	(1927)
SEP	**85.77**	77.99	7.77	**85.77**	**(1998)**	65.6	(1965)
OCT	63.29	65.79	-2.50	75.1	(1963)	50.8	(1969)
NOV	53.30	50.31	2.99	62.2	(1949)	33.0	(1929)
DEC	42.61	40.10	2.51	51.6	(1957)	22.4	(1983)
YEARLY AVE MAX TEMP	64.776 °F	62.636 °F	2.140 °F				

TABLE 3. AVERAGE MONTHLY MINIMUM TEMPERATURES

JAN	17.55 °F	12.43 °F	5.12 °F	22.9	(1953)	-5.3	(1937)
FEB	24.39	17.15	7.24	26.6	(1992)	2.2	(1936)
MAR	23.39	23.08	0.31	30.9	(1986)	11.0	(1912)
APR	29.33	32.40	-3.07	39.3	(1930)	26.1	(1920)
MAY	43.58	42.44	1.14	48.6	(1934)	36.5	(1917)
JUN	47.30	51.81	-4.51	57.7	(1956)	46.0	(1945)
JUL	60.42	57.88	2.54	62.6	(1966)	54.1	(1915)
AUG	55.90	56.09	-0.19	60.8	(1983)	52.2	(20&74)
SEP	51.07	46.71	4.35	52.6	(1963)	41.2	(12&45)
OCT	36.48	34.87	1.62	43.0	(1963)	28.9	(1917)
NOV	**29.40**	22.97	6.43	**29.40**	**(1998)**	14.0	(1929)
DEC	14.39	14.97	-0.58	21.9	(1946)	3.1	(1983)
YEARLY AVE MIN TEMP	36.100 °F	34.400 °F	1.700 °F				

TABLE 4. SUMMER GROWING SEASON RAINFALL, TEMPERATURE, AND GROWING DEGREE-DAY SUMMARY FOR USDA-ARS RESEARCH STATION, AKRON, COLORADO [1998 & 91-AVERAGE]

RAINFALL inches			TEMPERATURE DATA									
			AVERAGE MEAN TEMP Deg F		GROWING DEGREE-DAYS**		NUMBER OF DAYS 90 or ABOVE; 100 or Above; 55 or BELOW					
							AKRON – 1998			AKRON 91-YR AVE		
MONTH	1998*	AVG*	1998*	AVG*	1998*	AVG*	90+	100+	<55	90+	100+	<55
MAY	0.99	3.01	59.98	56.21	311.0	235.2	0	0	30	0.95	0.00	30.42
JUN	0.36	2.48	63.80	66.55	440.5	499.7	9	0	27	7.49	0.58	21.77
JUL	3.84	2.70	74.66	73.29	764.5	722.1	17	3	1	15.95	2.04	8.82
AUG	2.44	2.05	71.40	71.45	663.5	665.3	13	0	13	13.48	0.81	13.23
SEP	0.35	1.23	68.42	62.35	558.5	388.7	13	0	22	4.89	0.08	26.53
TOTALS	7.98	11.47	67.67	65.97	2738.0	2511.0	52	3	93	42.76	3.52	100.77

* 91-year average rainfall and temperature data(1908-1998): and number of days 90 or above, 100 or above, and 55 or less; at Central Great Plains Res. Sta., Akron, Colorado

** GROWING DEG-DAYS defined as number of days with daily mean temperature above a 50-degree F base. For example..Max = 85; Min = 53; Mean = (85+53)/2=69. Deg-Day unit = 69 - 50 = 19 GDD units.

AKRON GDD UNITS ACCUMULATED FROM MAY 1 THROUGH SEPT. 30.

TABLE 5. RAINFALL AMOUNTS BY MONTHS. USDA-ARS, AKRON, COLORADO

(Based on 8:00 am daily observation time)

MONTH	1998 TOTAL	91-YEAR AVE AVE. 1908-98	DEPART.	% OF AVERAGE	HIGH TOTAL	(YEAR)	LOW TOTAL	(YEAR)	1998 CUM	90-YR AV CUM	DEPART. CUM	% OF AVERAGE	MON
JAN	0.05 inches	0.33 inches	-0.28	14.9%	1.51	(1988)	0.00	(6 YRS)	0.05	0.33	-0.28	14.9%	JAN
FEB	1.26	0.35	0.91	361.5%	1.68	(1915)	0.00	(9 YRS)	1.31	0.68	0.63	191.7%	FEB
MAR	0.15	0.82	-0.67	18.2%	3.06	(1909)	0.00	(1908)	1.46	1.51	-0.05	96.8%	MAR
APR	0.77	1.65	-0.88	46.6%	5.19	(1915)	0.17	(1928)	2.23	3.16	-0.93	70.6%	APR
MAY	0.99	3.01	-2.02	32.9%	7.79	(1917)	0.13	(1974)	3.22	6.17	-2.95	52.2%	MAY
JUN	0.36	2.48	-2.12	14.5%	6.11	(1965)	0.19	(1952)	3.58	8.65	-5.07	41.4%	JUN
JUL	3.84	2.70	1.14	142.3%	7.22	(1946)	0.31	(1934)	7.42	11.35	-3.93	65.4%	JUL
AUG	2.44	2.05	0.39	118.8%	7.36	(1918)	0.16	(1973)	9.86	13.40	-3.54	73.6%	AUG
SEP	0.35	1.23	-0.88	28.4%	4.83	(1950)	0.00	(1978)	10.21	14.63	-4.42	69.8%	SEP
OCT	0.95	0.91	0.04	104.5%	3.71	(1993)	0.00	(3 YRS)	11.16	15.54	-4.38	71.8%	OCT
NOV	0.81	0.56	0.25	145.3%	2.67	(1946)	0.00	(3 YRS)	11.97	16.10	-4.13	74.4%	NOV
DEC	0.21	0.41	-0.20	51.0%	3.27	(1913)	0.00	(1908,28)	12.18	16.51	-4.33	73.8%	DEC
Total	12.18 inches	16.508 inches	-4.33	73.8%	26.79	(1946)	9.93	(1939,74)	12.18	16.51	-4.33	73.8%	

1998 DATA INCLUDED IN AVERAGE FINAL 1998 SUMMARY

Table 6. Snowfall Dates and Depths for Calendar Year 1998
USDA-ARS Research Station, Akron, Colorado

DATE	Snow Depth inches	Precipitation inches
Jan 6	Trace	Trace
Jan 9-10	Trace	Trace
Jan 11-14	Trace	Trace
Jan 22	1.00	0.05
Feb 1	Trace	Trace
Feb 6	Trace	Trace
Feb 9-10	3.50	0.65
Feb 16-17	Trace	0.22
Feb 25-26	2.00	0.39
Mar 8	0.50	0.05
Mar 11	Trace	Trace
Mar 19	0.50	0.10
Apr 3	Trace	0.31
Sub-Total	7.50	1.77
Nov 3	1.50	0.30
Dec 7	Trace	Trace
Dec 10	Trace	Trace
Dec 19-21	4.50	0.21
Sub-Total	6.00	0.51
TOTALS	13.50	2.28

1 9 9 8 RAINFALL

CENTRAL GREAT PLAINS RESEARCH STATION AKRON, COLORADO

PRECIPITATION LOG 1998 STANDARD GUAGE inches LOCATION: WEATHER STATION

[Rainfall amounts are for the period 12:00 midnight to 12:00 midnight for the date recorded.]

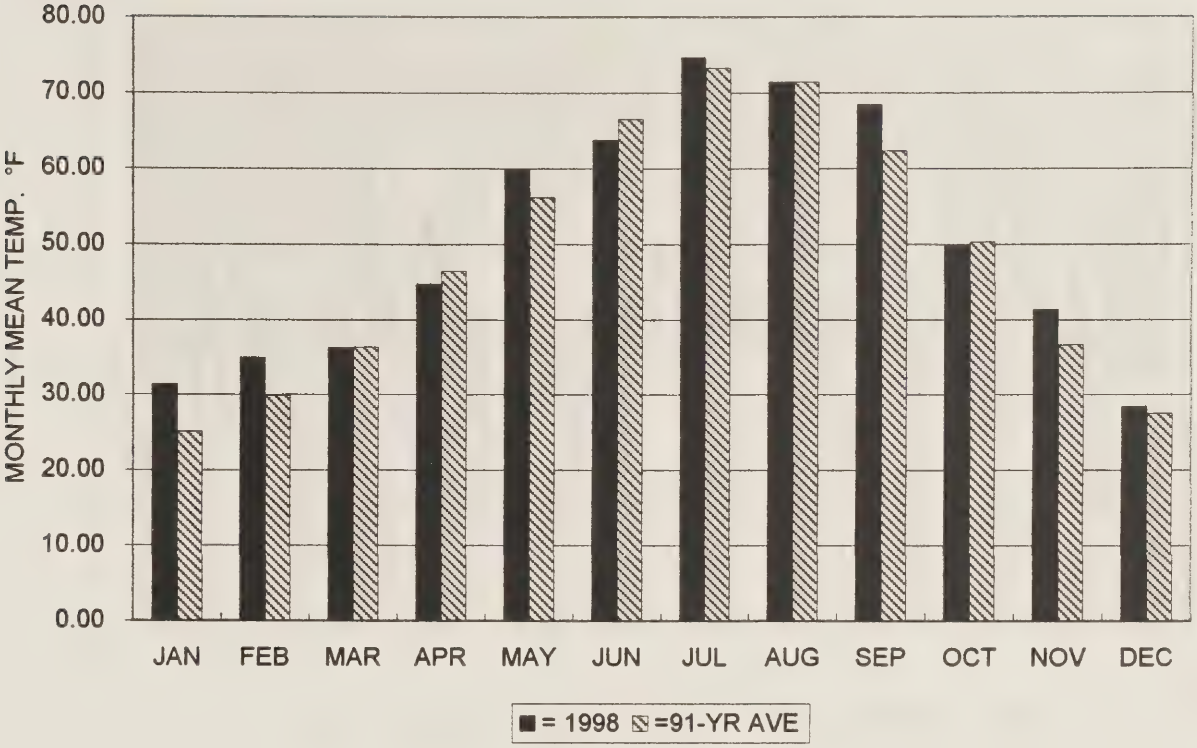
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1								0.44		0.18	0.10		1
2				0.22		0.03				0.13	0.30		2
3				0.09		0.02	0.03			0.05			3
4						T	0.80			0.11			4
5	T				0.07	0.05				T			5
6					0.07				T				6
7			0.05	0.06	0.22	T			T			T	7
8				0.29	0.12	T	0.27	0.03			0.05		8
9	T	0.52			0.06		0.19	0.76			0.25		9
10	T	0.13	T		T	0.01		0.03				T	10
11					0.02			1.18					11
12	T												12
13				0.05					0.04				13
14				0.06	T				0.07				14
15		0.09	T	T			0.62						15
16		0.13	T										16
17		T	T	T		T				0.02			17
18			0.10										18
19			T		0.05							0.03	19
20					0.06	T			0.01		T	0.04	20
21	0.05					0.15	0.11		0.21			0.14	21
22					0.27	0.10	0.20		T				22
23					T		0.54		0.01				23
24							0.18			T			24
25		0.39		T			0.20						25
26													26
27			T							0.05			27
28					0.05				0.01	0.10			28
29							0.45			T			29
30						T	0.22			0.13			30
31							0.03			0.29			31

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
SUM	0.05	1.26	0.15	0.77	0.99	0.36	3.84	2.44	0.35	1.06	0.70	0.21	MONTHLY TOTAL
AVE	0.33	0.35	0.82	1.65	3.01	2.48	2.70	2.05	1.23	0.91	0.56	0.41	<<91-YEAR AVE
DEP	-0.28	0.91	-0.67	-0.88	-2.02	-2.12	1.14	0.39	-0.88	0.15	0.14	-0.20	DEPARTURE
%NORM	14.9%	361.5%	18.2%	46.6%	32.9%	14.5%	142.3%	118.8%	28.4%	116.5%	125.9%	51.0%	MONTHLY % OF NORMAL
CUM	0.05	1.31	1.46	2.23	3.22	3.58	7.42	9.86	10.21	11.27	11.97	12.18	CURRENT ACUM
AVCM	0.33	0.68	1.51	3.16	6.17	8.65	11.35	13.40	14.63	15.54	16.10	16.51	AVE ACUM
DEP	-0.28	0.63	-0.05	-0.93	-2.95	-5.07	-3.93	-3.54	-4.42	-4.27	-4.13	-4.33	DEPARTURE
%of NORM	14.9%	191.7%	96.8%	70.6%	52.2%	41.4%	65.4%	73.6%	69.8%	72.5%	74.4%	73.8%	CUM % OF NORM

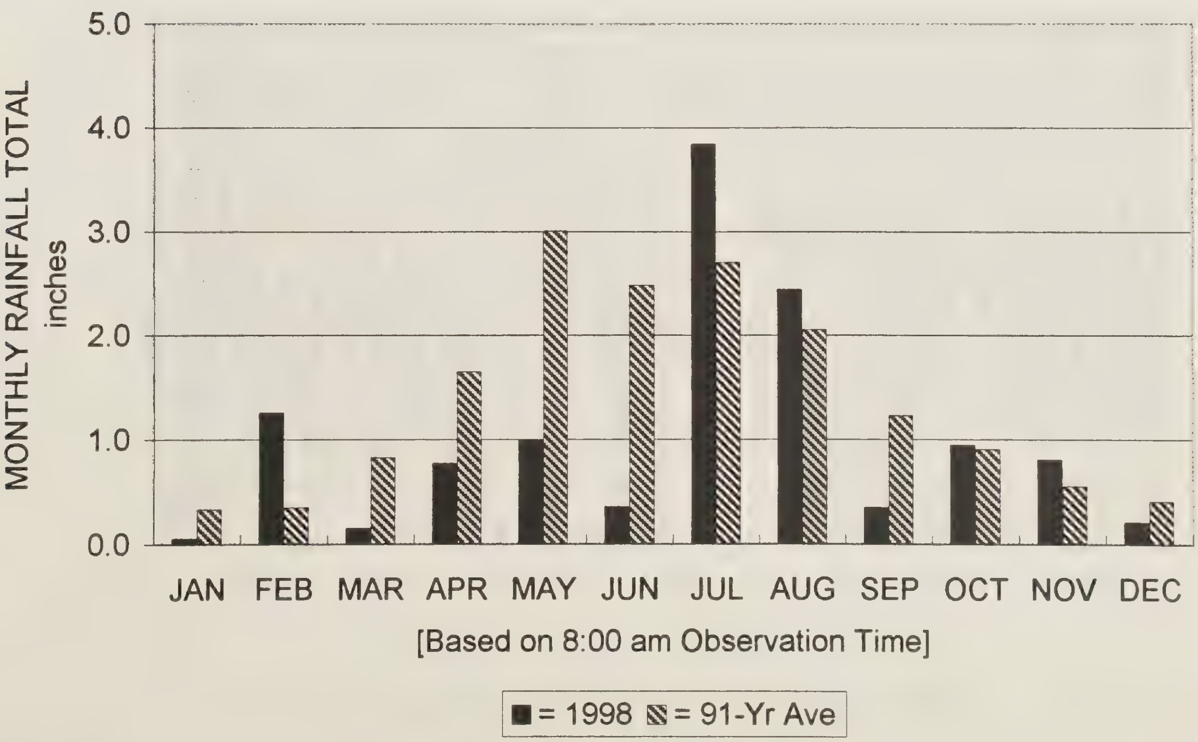
LAST UPDATE>> 31-Dec-98

NOTE: NEW MONTHLY AVERAGE IS CALCULATED.......NEW AVERAGE INCLUDES 1998 RAINFALL DATA

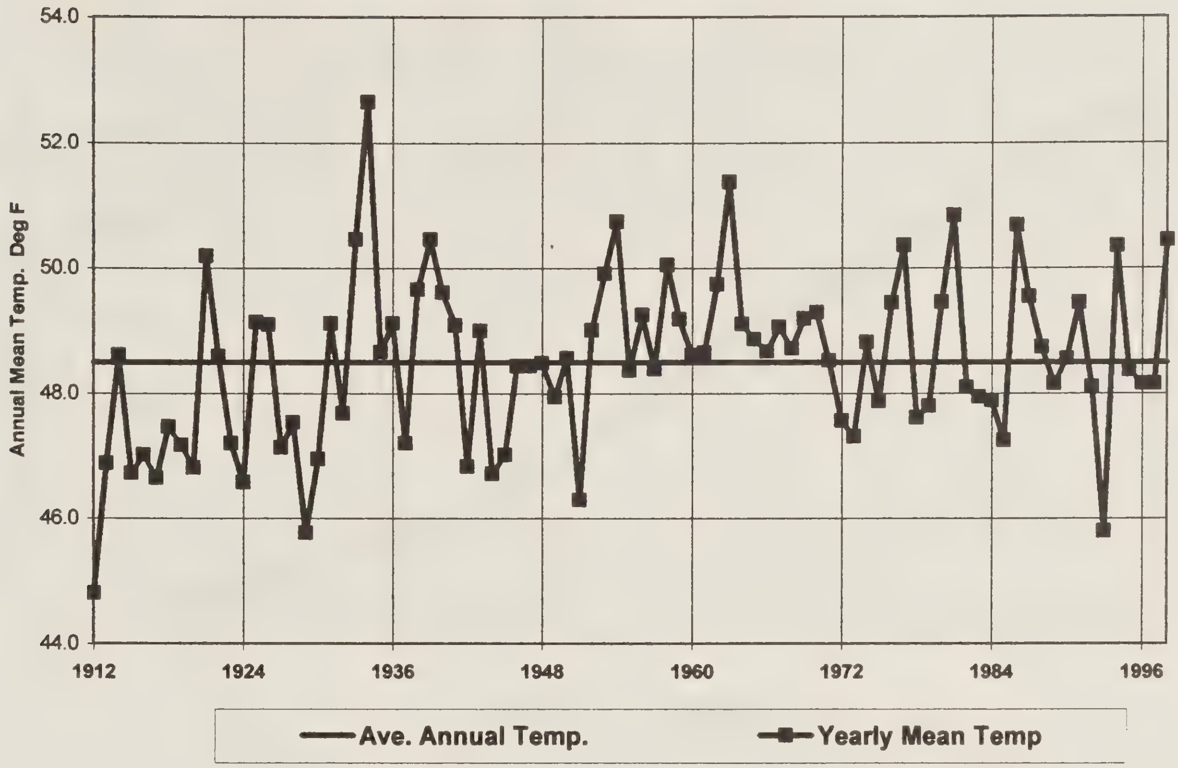
MONTHLY MEAN TEMP.: 1998 & 91-YR AV
USDA-ARS RESEARCH STATION, AKRON, CO



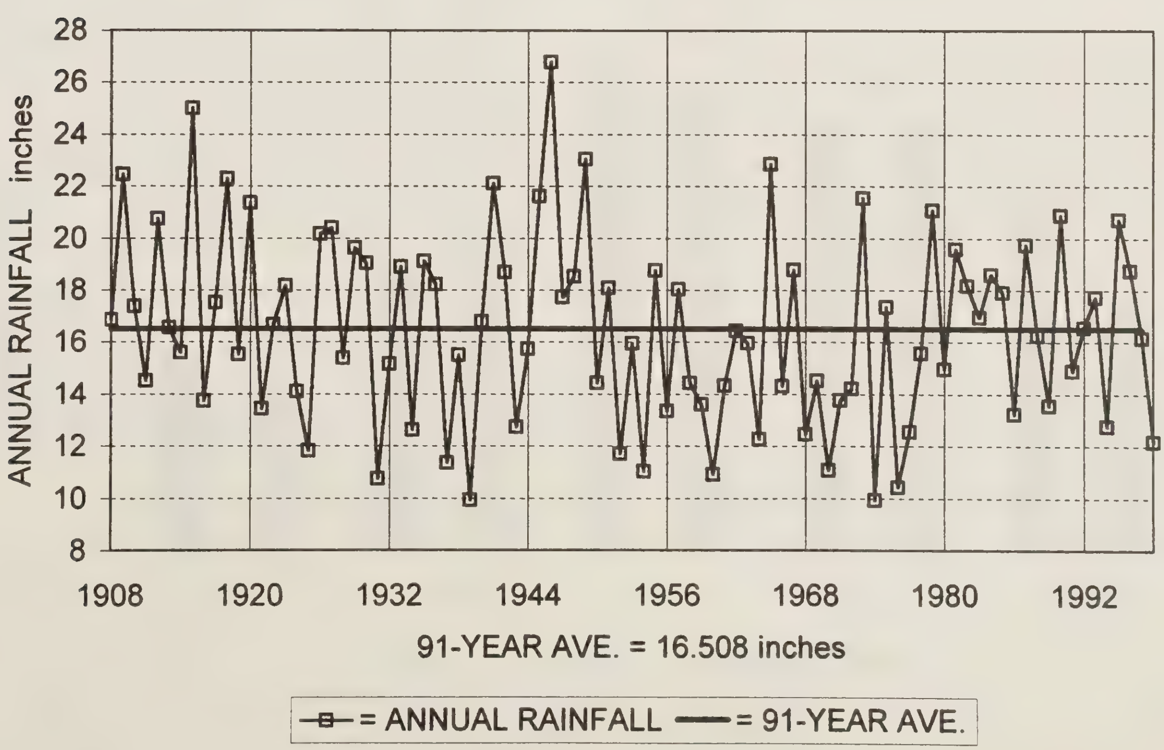
MONTHLY RAINFALL--1998 & 91-YR AVE
USDA-ARS RES. STA.,AKRON,COLORADO



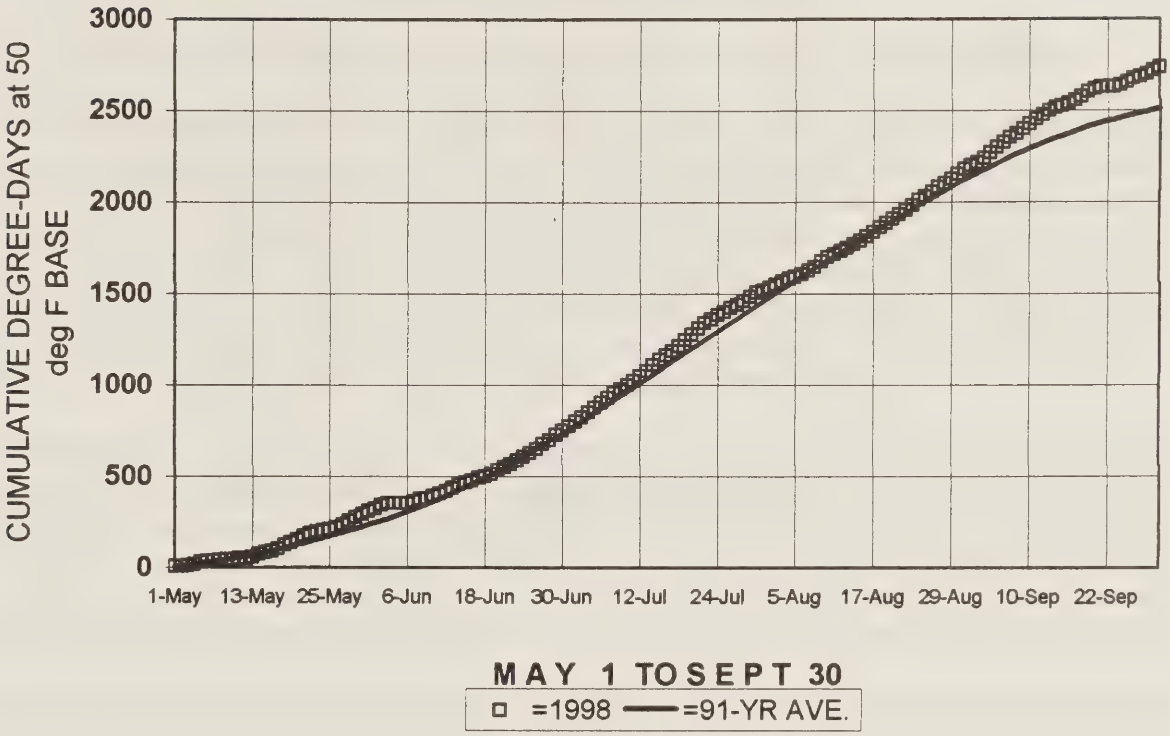
ANNUAL AVERAGE MEAN TEMP. Deg F
USDA-ARS Research Station, Akron, Colorado



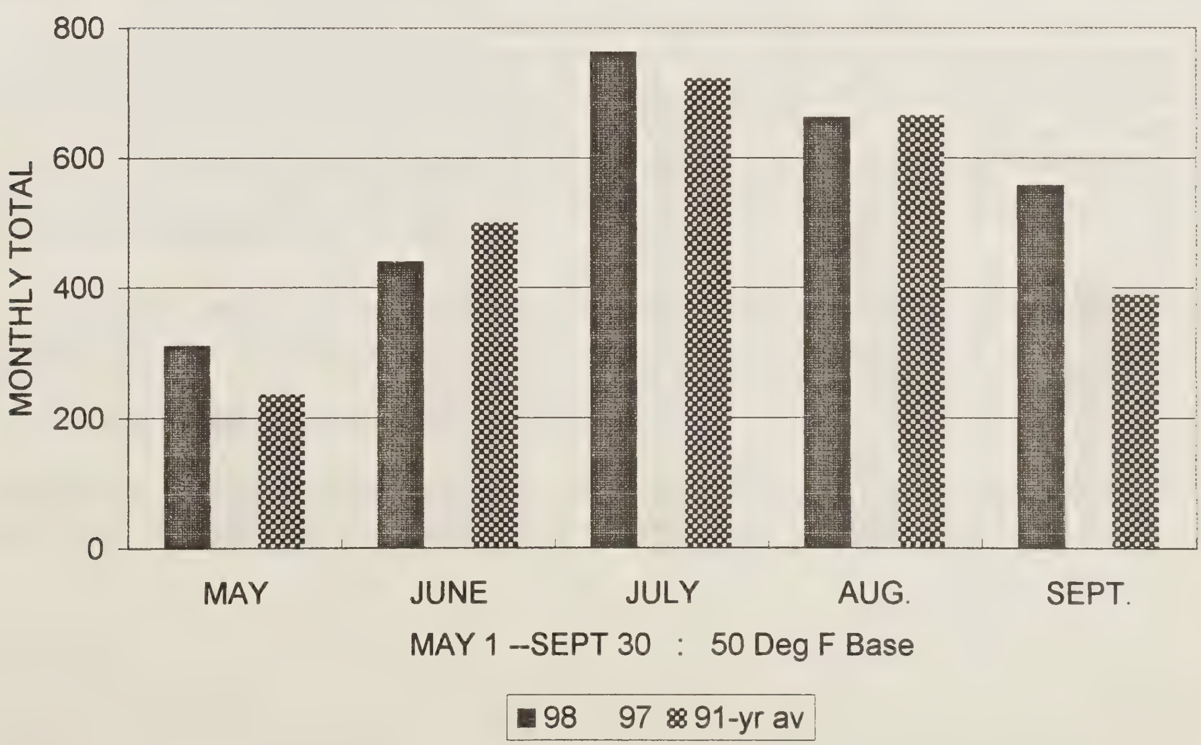
ANNUAL RAINFALL AKRON, CO 1908-1998
USDA-ARS RESEARCH STATION, AKRON, CO



GROWING DEG-DAYS: 1998 & 91-YR AVE
USDA RESEARCH STATION AKRON, COLORADO



MONTHLY DEG-DAY TOTALS: 1998,'97 & AVE.
USDA-ARS RESEARCH STATION, AKRON, CO



EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT - FALLOW

R.M. Aiken, J.G. Benjamin, D.C. Nielsen, R.A. Bowman, M.F. Vigil, R.L. Anderson

PROBLEM: Producers in the Central Great Plains rotate winter wheat with fallow; fallow enables producers to stabilize wheat production. However, fallow degrades soil by increasing loss of organic matter and organic nitrogen while exposing soil to wind and water erosion. Producers can counter this trend in soil degradation by cropping more frequently. Improved weed control methods during non-crop periods have increased precipitation storage efficiency such that more soil water is available for crop growth. Also, new crop varieties are more efficient in converting water into grain, thus the need for fallow may be less than historically perceived. This study is evaluating crop rotations to increase cropping intensity and subsequently, reduce the amount of fallow.

APPROACH: A crop rotation study with 16 rotations was initiated in 1990 on a Weld silt loam at the Central Great Plains Research Station. Crops include: winter wheat, corn, sunflower, proso millet, foxtail millet, field pea, and triticales. With all rotations, we are minimizing tillage. Tillage is required to incorporate herbicides for sunflower. Three tillage systems, conventional-, reduced-, and no-till, are included in the wheat-fallow rotation as a basis for comparing soil quality changes. Standard agronomic practices for seeding rates, planting dates, varieties, and weed control are being followed.

RESULTS: Precipitation during March through June was the lowest recorded in the history of the station; 28% of normal. Consequently, wheat yields averaged only 30 bu/ac. Wheat yields were increased with more diverse rotations; wheat in W-C-M-F yielded 34% more than in W-F. Over the past 5 years, the rotation effect on wheat yield has been greatest in dry years. Summer annual crop choice can disrupt the rotation effect; sunflower in the rotation decreased wheat yields 40%, even though a fallow period preceded wheat.

Precipitation was favorable during July and early August, thus summer crops survived the spring drought. Corn yielded between 40 and 53 bu/ac, with highest yields in W-C-F and W-C-M-F. Proso yield was highest in W-C-M, whereas following sunflower, proso yielded only 22% compared to corn as the previous crop. Sunflower yielded the most when grown in 4-year rotations. Sunflower in W-S-F yielded 52% of sunflower in 4-year rotations; part of the yield loss was caused by lodging due to phoma, a soil-borne fungus.

The data is confirming our hypothesis that a 4-year rotation with different crops is the most favorable for producers to maximize the rotation effect, minimize plant diseases, and control weeds. We are evaluating W-W-C-M and W-C-M-Pea to test if the rotation effect can be enhanced by including a low-water-using broadleaf crop such as pea.

FUTURE PLANS: The W-C-M-Pea rotation will be managed based on pea water use; pea will be harvested for forage or managed as green fallow after pea has used 7 inches of water.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

D. Schutz[1], R.L. Anderson

PROBLEM: The Central Great Plains Research Station is exploring alternative crop rotations, with the goal of increasing cropping intensity and consequently, crop diversity. The CSU Eastern Colorado Research Center (ECRC) at Akron is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and markets for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage). The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of crop aftermath and alternative forages while reducing annual cow costs.

APPROACH: An integrated crop-livestock study was initiated in the fall of 1998 at the ECRC. Three cropping systems are being compared: 1) W-C-Proso-Pea (as green fallow); 2) W-C-Proso-Austrian winter pea; and 3) Triticales-W-C-Foxtail millet-Austrian Winter pea-Foxtail millet. The cropping aspect of this study will supplement the Alternative Crop Rotations Study at the ARS station, as the soil type at the ECRC is an Ascalon sandy loam, contrasting with the Weld silt loam at the ARS site.

With systems 2 and 3, grazing will be integrated with selected crops. Corn stalks will be grazed during winter; foxtail millet will be swathed, with the swaths grazed in the fall; Austrian winter peas will be grazed in early summer; and triticales will be grazed either in the fall or spring, or harvested for hay, depending on range conditions as affected by seasonal precipitation.

Breeding will be managed for calving to occur in late April, which coincides with available forage with either triticales or Austrian winter peas. Austrian winter peas will be grazed in early summer by calves after weaning. Livestock will be the cow-calf herd maintained on the ECRC station, and weight gain and condition score will be measured.

RESULTS: For the systems study, wheat, triticales, and Austrian winter peas were established in early September, with excellent stands due to favorable fall moisture conditions. Livestock grazed triticales during the fall.

Two fact sheets: oat for forage, and foxtail millet for forage, are being distributed to producers at field days and winter meetings.

FUTURE PLANS: Our long-term objective is to develop integrated production systems for diversified farms that incorporate more intensive cropping with alternative cattle feeding programs. We will focus our future efforts on the systems study at the ECRC station.

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[1]Eastern Colorado Range Station, Akron

ECOLOGICALLY-BASED WEED MANAGEMENT SYSTEMS

R.L. Anderson

PROBLEM: Cropping patterns are changing in the Central Great Plains from wheat-fallow to more intensive crop rotations. One major contributing practice leading to this change is replacing tillage operations with herbicides for weed control.

However, public environmental concerns with the use of herbicides may limit or even eliminate future herbicide options. Secondly, several crops grown in this region do not have registered and effective herbicides for in-crop weed control. Because of these potential limitations, producers need non-chemical weed control methods. Cultural practices as alternatives to herbicides have been evaluated, but results suggest that their effect will be inconsistent. A complementary approach to cultural strategies is to devise strategies that improve the inherent strengths of a cropping system, subsequently minimizing weed populations.

Our goal at the Central Great Plains Research Station is to develop ecologically-based cropping systems that emphasize the systems' inherent strengths. To achieve this goal, we are examining the effect of cultural strategies on weed dynamics during various segments of alternative cropping systems.

APPROACH: With this systems approach, our efforts are focused in three areas: rotation design, crop residue management, and development of cultural systems within wheat, corn, sunflower, and proso millet. Two aspects of this approach are now completed, and summarized below. Cultural systems are currently being examined and reported in later reports.

RESULTS: Rotation design: Weed biomass is reduced 4-fold by growing two summer crops in 4 years compared to two summer crops in 3 years. We are integrating this concept with our design of new rotations in the Unit's cropping systems study, and are focusing on rotations with a balance of winter/spring crops with summer crops.

Residue Management: With cultural systems in wheat, residue production can be increased to levels that reduce weed densities 25 to 40% in following crops such as corn or sunflower. The threshold level for effect is 3000 lbs/acre of crop residue on the soil surface at corn or sunflower planting.

Cultural Systems: Results indicate that weed biomass can be reduced 70 to 95% with cultural systems comprised of at least 3 cultural practices (see research report on cultural systems).

FUTURE PLANS: Our final goal is to integrate these strategies with crop sequencing, thus devising crop rotations that minimize weed densities. This approach should enable producers to reduce herbicide inputs. We will be testing the effect of crop diversity on managing weed populations also.

CULTURAL SYSTEMS FOR WEED CONTROL IN SUMMER ANNUAL CROPS

R.L. Anderson, D.L. Tanaka[1]

PROBLEM: Producers are seeking production practices that reduce pesticide use for economic and environmental reasons. Cultural practices, such as narrow rows and increased plant populations, may enable producers to enhance crop competitiveness to weeds. For example, by reducing row spacing from 76 to 38 cm and doubling the planting population of corn, producers can reduce herbicide use in the Eastern U.S. by 75% without reducing weed control. These cultural practices also may work with summer annual crops in the Central Great Plains.

Research with cultural practices usually focuses on the effect of one or two practices on weed control, but does not evaluate systems based on several cultural practices in combination. This study is examining the impact of cultural practice systems on weed growth and interference in corn and sunflower. The ultimate goal is to develop a cultural system that will eliminate need for herbicides or if needed, will favor reduced rates of herbicides.

APPROACH: Sunflower. We are comparing cultural systems comprised of row spacing (15 versus 30-inch), planting population (16,000 vs 20,000), and delayed planting (early June vs 2-week delay). Weed biomass is measured when sunflower begins to flower. Seed yield and oil content are measured at harvest. Each plot is split into a weed-free and weed-infested sub-plots. Weed-free subplots have Prowl applied for in-crop weed control, and escaped weeds are pulled by hand.

Corn. Cultural systems comprised of N fertilizer placement (banding vs broadcast), planting population (15,000 vs 19,000), and row spacing (15 vs 30-inch) were evaluated for impact on weed growth and grain yield. Each plot was split in two, with one half maintained weed-free by herbicides and hand weeding. Foxtail millet was planted in the weed-infested subplots, as an indicator species to measure impact of cultural systems on weed growth. Weed biomass was harvested when corn began tasseling. Grain yield was determined for both weed treatments.

RESULTS: Sunflower. Cultural systems reduced weed biomass by 95%. A key component of this system is delayed planting, which has a negative consequence of reducing seed and oil yield. Narrow rows at later plantings increased grain yield compared to wide rows, thus minimizing yield loss with delayed planting. Yield loss in the weed-infested conventional system was 28%; the cultural system with narrow rows, 20,000 plants, and delayed planting lost only 9% yield due to weeds.

Corn. A cultural system combining three cultural practices; N banding, 15-inch row spacing, and 19,000 plants/acre, reduced weed biomass 70%. If only one or two practices were used, the impact on weed biomass was reduced by at least ½. Grain yield in the conventional system (N broadcast, 15,000 plants/acre, and 30-inch rows) was reduced 41%. In contrast, weed loss with the three-cultural practice system was only 10%. Narrow rows increased grain yield 7%.

FUTURE PLANS: Cultural systems will be evaluated in corn and sunflower again. We are starting an integrated rotations study, where long-term weed densities will be monitored for 4 years.

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[1]USDA-ARS, Mandan ND

CULTURAL SYSTEMS FOR WHEAT PLANTED INTO WHEAT AND PROSO STUBBLE

R.L. Anderson

PROBLEM: Our rotation study suggests that a 4-yr rotation with two winter crops followed by two summer crops may be the most favorable for producers to maximize the rotation effect and control weeds. One promising rotation is W-W-C-M. The highest productive rotation currently in our rotation study is W-C-M. Thus, if producers use these two rotations, wheat will be planted into either proso or wheat stubble, with corn following wheat the next year. Cultural systems in wheat reduce weed populations in future crops if greater than 3000 lbs of residue remains on the soil surface. With residue management, producers may be able to reduce herbicide inputs in continuous cropping. A second concern is that low crop residue levels of wheat in continuous cropping may reduce yields of corn, thus strategies for wheat residue management may improve continuous cropping rotations.

The objective of this study is to develop cultural systems in wheat that favor wheat growth, and reduce the weed population in the following corn crop grown in sequence. These cultural systems will be evaluated in both proso and wheat stubble, to guide management decisions for continuous cropping.

APPROACH: Two varieties, Alliance and Lamar, have been planted with the hoe drill (12-in row spacing) and the JD 750 drill (7.5-in row spacing). Two nutrient management systems were applied: N broadcast vs band application. With the band system, P was banded with the wheat seed. Total N in both systems is 60 lb/ac. The rate for P is 10 lb/ac. Planting rate is 650,000 seeds/acre.

The plots are being split for weed control, with green foxtail seed broadcast in one half of each plot. Foxtail populations will be assessed in the following corn crop in both stubble treatments.

Measurements in wheat: Stand counts will be assessed 3 weeks after emergence, with green foxtail and other weeds counted in early May. At maturity, yield and yield components for wheat will be determined. Crop residue levels will be measured after wheat harvest and at corn planting.

Measurements in corn: The split plots will be managed differently. The split plots with green foxtail will not be treated with herbicides. Green foxtail populations and biomass will be determined during the crop year. The weed-free plots will be treated with herbicides. Final grain yield of both treatments will be determined at maturity.

RESULTS: Wheat yields were not affected by cultural systems nor previous crop; yields were low because of the driest spring in 90 years. Wheat planted into wheat stubble had 2-fold more tillers than wheat in proso, which reflects the greater soil water levels at planting time in wheat stubble; however, the drought eliminated this potential yield advantage. Biomass production among treatments ranged between 2500 to 3500 lbs/acre.

FUTURE PLANS: Corn will be planted into the first set of plots in 1999, and a second set of wheat plots was established in the fall of 1998.

RAINDROP AND CROPPING SYSTEM EFFECTS ON SURFACE SOIL PERMEABILITY AND EROSIVITY

R.M. Aiken, J.G. Benjamin, R.A. Bowman, M. Sucik[1], L.R. Ahuja[2], G. Dunn[2]

PROBLEM: Surface soil crusts, formed by raindrop impact on exposed soil, restrict infiltration, soil aeration, and seedling emergence. Crusts can limit soil intake of water from intense rains of convective thunderstorms. Surface crusts limiting infiltration can reduce the quantity of water available for dryland cropping systems in the region; runoff associated with surface crusts can lead to soil loss as well. Previous studies indicate crust formation depends on rainfall intensity, soil characteristics (texture, cation composition, soil organic matter) and soil wetting conditions prior to rainstorm events.

APPROACH: We simulated rainfall (> one in. hr^{-1}, two hour duration) and residue cover (0% or 100%) for cropping intensities ranging from 50% (wheat-fallow, conv. till, WF_CT; wheat-fallow, no-till, WF_NT), 67% (wheat-corn-fallow, no-till,WCF_NT), to 100% (wheat-corn-millet, no-till, WCM_NT). Rain simulation occurred in the spring, after the previous wheat harvest and prior to soil tillage. We measured surface soil strength, texture, organic carbon, aggregation (wet and dry) for each replicate plot; and transport capacity for water and air after crust formation.

RESULTS: Preliminary analysis of results indicates intensive cropping improved surface soil permeability (0.3 in. hr^{-1} for WCF_NT relative to 0.04 in. hr^{-1} for WF_CT and 0.1 in. hr^{-1} for WF_NT). Potential soil loss from bare soil ranged from 4.5 to 13 T/A; residue cover (simulated) resulted in 0.2 to 2.5 T/A soil loss potential.

FUTURE PLANS: The experiment is complete. Following data analysis, a manuscript and fact sheet will report raindrop and cropping intensity effects on soil permeability and erosion potential.

[1]USDA-NRCS Soil Quality Team
[2]USDA-ARS Great Plains Systems Research

TILLAGE AND CROP ROTATION EFFECTS ON SOIL PHYSICAL PROPERTIES

J.G. Benjamin, C.A. Reule

PROBLEM: Twenty million acres of non-irrigated land in the Great Plains are farmed with clean-till wheat-fallow (W-F) rotation. Studies at the Central Great Plains Research Station (CGPRS) at Akron, Colorado, have shown that inserting summer annual crops such as corn, millet, or sunflower into the rotation leads to a beneficial rotation effect. A cause for this effect could be an improved soil physical condition resulting from greater plant root activity (from the greater cropping intensity) or less destruction of soil structure and porosity (from the switch to fewer tillage operations). An improved soil physical condition could result in an increase of plant available water, less soil crusting, and better water infiltration. The objective of this study is to investigate changes in soil hydraulic properties, and subsequent changes in plant available water and water usage, caused by intensifying the crop rotation and decreasing tillage used for crop production.

APPROACH: An evaluation of soil hydraulic property changes caused by tillage and crop rotation was initiated in 1996. Samples were collected from the Alternative Crop Rotation (ACR) study at the Central Great Plains Research Station in Akron, CO.

The rotations selected for study included: 1. wheat-fallow, conventional tillage (sweep plow 3 to 4 times during fallow); 2. wheat-fallow, no tillage; 3. wheat-corn-fallow, no tillage; 4. wheat-corn-sunflower-fallow, no tillage; and 5. wheat-corn-millet, no tillage. Field measurements of ponded infiltration rate, tension infiltration rates at -3 and -6 cm water head, and penetrometer resistance were taken in the spring of 1997 for comparison with samples taken in the fall of 1996. Soil cores were collected from the same plots for laboratory measurements of bulk density, saturated hydraulic conductivity, water diffusivity and water retention characteristics.

RESULTS: The crop grown had a greater effect on soil hydraulic properties than the long-term rotation. The fallow plots had the greatest ponded infiltration rate, but similar tension infiltration rates compared with the other plots, indicating larger macropore flow for fallow. Millet and grass plots had similar infiltration characteristics, showing less macropore and more matrix water flow than the other treatments. Slopes of unsaturated hydraulic conductivity (K_{unsat}) function were similar among soils from all crop treatments in fall and in spring. Plots which had corn or millet crops tended to have greater conductivity at a particular water content than for the other plots in the fall. Slopes from soils sampled in the spring were not as steep as from soils sampled in the fall. K_{unsat} differences among crops were not as apparent in the spring as in the fall, indicating a suppression of crop-induced pore changes during the winter. Similarities among the soils from the different crops indicate the possibility of developing scaling functions to normalize soil hydraulic characteristics among crops and crop rotations.

FUTURE PLANS: We plan to continue to analyze hydraulic conductivity and porosity properties to scale plant-induced changes of soil hydraulic properties. We plan to use this information when working with the Great Plains Systems Research Unit in modeling crop rotation management.

MANAGING SOIL COMPACTION TO ENHANCE CORN PRODUCTION AND SOIL BIOLOGICAL ACTIVITY

J.G. Benjamin, M.F. Vigil, D.C. Nielsen

PROBLEM: Sustainability of agriculture demands that soil resources remain productive. Degradation of soil resources is of particular interest in the Great Plains because relatively low soil organic matter levels make these soils very susceptible to many adverse soil management effects such as compaction. Most compaction research has addressed changes in soil physical characteristics, but less research has addressed the effects of these physical changes on plant productivity and biological activity. In order to manage compaction, we need information on the soil environment created by varying compaction levels and information on the compaction level tolerated by plants. The goals of this research fall within three broad categories: 1) Evaluate current concepts of soil mechanics as related to soil compaction; 2) Gain information about the soil environment and plant response to soil environmental changes caused by compaction to further understand the interaction between the soil and the plant; and 3) Test the effectiveness and longevity of methods to alleviate soil compaction.

APPROACH: We have established a study of soil compaction effects on corn (*Zea mays*, L.) growth and soil biological activity at Akron, Colorado, on a Weld silt loam (fine smectic, mesic Aridic Paleustolls). We included 3 levels of wheel traffic (0, 2, and 8 passes of a 7700 kg tractor) and 5 methods of compaction alleviation: 1) no alleviation from tillage; 2) shallow (20 cm deep) chisel plow tillage conducted only at the start of the experiment; 3) shallow chisel plow tillage conducted yearly during the experiment; 4) deep (45 cm deep) chisel plow tillage conducted only at the start of the experiment; and 5) deep chisel plow tillage conducted yearly during the experiment. The field was planted to corn in the spring and plant growth characteristics were measured throughout the growing season to determine compaction effects on corn productivity. We took soil samples in the fall after harvest to determine yearly changes in the soil physical properties (bulk density, soil strength, infiltration, and water retention characteristics) caused by compaction and compaction alleviation.

RESULTS: Corn yields were lower from the non-compacted, deep chiseled plots than for the other treatments. This could indicate a too-loose soil condition for optimum plant growth. We are examining crop water use, recharge from irrigation, and physiological response to give indications for these results.

FUTURE PLANS: We will continue the analysis of 1998 growing season data to examine the soil conditions leading to the yield differences. We will examine the plant growth information to determine if physiological changes in the plants can be related to soil conditions. We will continue the experiment in 1999.

METHOD DEVELOPMENT FOR EVALUATING AND QUANTIFYING SOIL QUALITY

R.A. Bowman, NRCS Soil Quality Team[1]

PROBLEM: In the semiarid areas of the Great Plains, continued clean-till wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of wind erosion and decomposition. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical and biological properties such as rooting depth, water storage and soil aggregation. Total pools of organic C in croplands are sometimes inadequate as predictors of trends in soil deterioration because they may lack sensitivity over the short term (1 to 3 years); but over the long term, this may not be the case. A need exists, therefore, to develop methodology to assess soil quality changes and direction of change. Our specific objective is to develop easy sensitive laboratory and field methods based on SOM content and other soil parameters to assess soil quality, and consequently, long-term soil productivity in croplands.

APPROACH: Our intent is to develop a quantitative index, which hopefully, will integrate losses in SOM due to erosion, decomposition, and nutrient uptake, and gains due to fertilization and net residue inputs and organic matter content from previous cropping. Besides measurement of SOM, labile organic C pools, enzyme activity, and other biologically based pools, bulk density (BD) and depth to lime (solum) are also measured. Thus, a Soil Quality Index (SQI) for new rotations other than wheat-fallow conventional-till is assessed based on SOM in the top 15 cm, the solum (kg organic carbon/m^2) or a predetermined depth (60 cm for cumulative organic mater index (COMI)). Additionally, a structural index (S_t) based on ratio of SOM % to clay % is also assessed to determine potential for degradation. Values for new crop rotations can then be compared to soils of the traditional wheat-fallow or with an adjacent native sod.

RESULTS: A fact Sheet has been published on: Soil Quality Indicators for Whole-Farm Management in the Central Great Plains. This sheet discusses some of the more important chemical, physical, and biological processes that affect soil quality, and some principles to improve soil quality and productivity. The new modified field method for approximating SOM is being used with positive results regularly by the Akron NRCS Soil Quality Team in the Central and Northern Plains states. The method is mostly used for screening purposes where differences of greater than 0.5% SOM are required. The method, when used every three to five years, can show differences in SOM between contrasting cropping systems and management techniques.

FUTURE PLANS: Future work will continue with the NRCS Soil Quality Team. This team visits farmers and ranchers monthly across the Great Plains, and has a feel for the practical needs of producers. While there is a much greater interest in SOM now than 10 years ago, education emphasis is on longer reduced- or no-till rotations and less fallow to increase residue which will ultimately conserve more water, reduce erosion, and increase productivity. Field measurements for compaction, infiltration, presence of earthworms, pH, salts, and nitrates, in addition to SOM, will continue on selected farmers fields for direct comparison of W-F with longer reduced-tillage rotations.

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[1]Mike Sucik, Manuel Rosales, and Josh Saunders.

SOIL ORGANIC MATTER CHANGES UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

R.A. Bowman, M.F. Vigil, R.L. Anderson, D.C. Nielsen, J.G. Benjamin

PROBLEM: Soil organic matter is important to hold the soil together, to easily infiltrate water, to reduce compaction, and to provide nutrients such as N, P, K, S, and micronutrients. However, the conversion of Great Plains grassland to clean-till small grain farmlands since the mid 19th century has resulted in extensive loss of the native SOM because of wind erosion and decomposition. On a global basis with about 40% more organic carbon residing in the SOM than in the terrestrial plant biomass, it is easy to see how the conversion of grassland to wheat-fallow could create over time a drop in crop production and a significant increase in global CO_2. On the other hand, if we intensify the cropping system over the W-F, and minimize soil disturbance through less tillage, and if we manage water, fertilizer, and pests efficiently, we should be able to reverse SOM loss and increase soil productivity. Our objective, therefore, was to evaluate different cropping systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, and organic matter buildup. This report focuses on changes in SOM.

APPROACH: The study is located at Akron, CO on a predominantly Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Anderson, Nielsen, Bowman, and Vigil for treatments). Extensive sampling was conducted on all 180 sites for soluble (dichromate oxidation) and total SOM and POM and total organic C and N (C-N analyzer). Soil samples were collected at 0-2 inch, and at 2-6 inch depths for pH and nutrient stratification and for plow layer evaluations especially under the no-till conditions and mixing under conventional-till. Soil samples on different soil series were taken to 5 feet depth. Some measure of aggregate stability against wind erosion is assessed. Cumulative OM Index (COMI) and solum SOM will be assessed every 3 to 5 years.

RESULTS: A manuscript has been published (February, 1999) on soil organic matter changes with respect to total soil organic carbon, soluble organic carbon, and particulate organic matter carbon. Three comparisons for SOM (cropping intensity, same length rotations but with different crop sequencing, and rotations in 1993 versus same rotations in 1997) all showed that carbon increases were occurring primarily in the 0-2 inch depth because of lack of fallow or from continuous cropping which generally on an annualized basis, provided greater total biomass than rotations with fallow. Continuous cropping showed about a 20% increase in SOM over wheat-fallow for the surface two inches.

FUTURE PLANS: Since rotations have been established for over 8 years, an attempt will be made to assess in more intensively cropped rotations, stabilized or humic carbon for losses or gains relative to the conventional winter wheat-fallow rotation which receives less carbon inputs. The relationship between surface crop residue and roots to six inches relative to SOC and POM-C will also be investigated.

NUTRIENT, CEC, AND pH CHANGES UNDER ALTERNATE CROPPING SYSTEMS

R.A. Bowman, M.F. Vigil

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (50 bushel dryland wheat requiring about 75 kg N and about 12 kg P, with 80 bushel dryland corn requiring about 80 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate nutrient availability and cycling under W-F and alternate cropping systems where more residue is returned to the soil surface, and consequently, more nutrients recycled from within the soil profile. Information is needed for P, S, and Zn use efficiency for subsequent crops such as corn and millet or oil crops or legumes after wheat in a reduced-till rotation.

APPROACH: In a Weld silt loam, various nutrient parameters were measured at the 0-2 and 2-6 inch depths to assess availability and cycling in selected plots from our alternate cropping and tillage system study (ACR). These parameters included available P pools such as those extracted by bicarbonate and anion-exchange resins, total soil P, and total soil organic P, residual P and phosphatase activity which is a measure of quickly available organic P. Available S and micronutrients were also evaluated in the surface 6 inches. Because of yearly N applications in continuous cropping systems, pH and CEC changes were also assessed. We also are assessing S levels because of our oil crops, and Zn because of corn.

RESULTS: Data from 15 different rotations from all replications showed that spatial variability generally was a more dominant factor than cropping intensity in assessing CEC, sulfate-S, Zn, and other nutrients. There was generally no correlation with cropping intensity as we saw with P and SOM. Results from the continuous cropping plots, however, generally showed lower pH (<5.5 at the 0-6 inch depth), lower exchangeable Ca (17 to 20% saturation instead of the 40% generally), and higher available Mn (100 to 200% higher) than rotations with fallow. There was a tendency for the continuous cropping rotations to contain higher residual profile nitrates than the other rotations. Electrical conductivity for the plots were generally <1.0 mmhos/cm. CEC at the 0-6 inch depth varied from 12.5 meq/100 g to 17. Zinc levels were generally <1 ug/g, and S < 5 ug/g. For S there was a slight correlation with SOM.

FUTURE PLANS: We will continue to monitor nutrient data on ACR plots since we are only resupplying N and P. Role of residue in buffering pH changes (cation production), and in resupplying the other nutrients are still factors for future considerations. We will also monitor some of the soil S levels in Vigil's research plots with wheat, proso millet, and sunflower treatments.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

R.A. Bowman, R.L. Anderson

PROBLEM: Present Center projects relevant to CRP address soil and vegetation changes on small station plots. Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible Cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested Cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Six farms in Washington County on the Conservation Reserve Program were selected from data obtained through SCS. Two went into the program in 1986, two in 1988, and two in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP (regenerative system). We also studied the take-out of CRP lands under different grass control systems to recrop. Soil parameters measured included: SOM, POM soluble organic carbon, TKN, available P, and pH. Soils were sampled at 0-5 and 5-15 cm with a minimum of three field replications with five composites. Forage quality was also evaluated.

RESULTS: Soils and plant data were not collected from all the six sites in 1998 because of difficulties in getting written permission for revisits, and conversion of some areas back to cropping. Since one of the concerns about the CRP program had to do with the poor quality of the grass, and subsequent low soil quality, we evaluated the CRP forage (grass and litter) collected in June/July 1997 for N content, acid-detergent fiber (ADF), cellulose, lignin, and carbon. While the CRP site with the lowest SOM content showed the lowest N uptake in the aboveground grass and litter (0.67% total soil organic carbon, and 1.69 g N / m^2 uptake), and therefore, the lowest potential to recycle N back to the soil, the other CRP sites with SOC >0.9% showed variable N uptake (2.84 g N to 756 g N). The C/N ratio was more a function of the mix of grass to litter (litter having about one-half the carbon content of grass) than of SOC content. Generally, the litter contained less cellulose but more lignin than the grass.

FUTURE PLANS: Data should be written up in 1999, and project terminated. Selected sites may be sampled where obvious data irregularities may exist. There is still a need to assess grass species composition of the CRP and native sites, but this will require help from the NRCS range specialist at Akron.

ORGANIC MATTER AND NUTRIENT CHANGES IN SIMULATED EROSION STUDIES

R.A. Bowman, M.F. Vigil

PROBLEM: Soil erosion is a serious problem in the Semiarid Plains. Its effects on water storage and nutrient availability have been extensively studied. Restoration with fertilizer or manures, and its effects over the long term are less well understood. Greb originally, and Smika later, conducted studies in the mid-50s with simulated erosion plots (different amounts of top soil removed) and added fertilizer. They removed from zero to 38 cm (15 inches) of top soil across the field. They were using added fertilizer to replace eroded topsoil in maintaining grain yields. We are presently revisiting these sites to evaluate long-term changes in selected chemical and physical properties (1956 vs 1996), and to assess presently, water use, crop yield and restoration potential of SOM with different fertilizers and amendments under more intensive and diverse cropping than the traditional wheat-fallow.

APPROACH: Hairy vetch was seeded as green manure in the spring on half the plots in an alternate vetch no-vetch format across the simulated erosion gradient. After 4 weeks, roundup was applied to kill cover and conserve water. In the fall prior to wheat seeding, a high rate of P (60 lb P2O5/acre), and a low rate (15 lb P2O5/Acre) were applied across the simulated erosion gradient so that both rates of P were contained in the vetch and in the no-vetch plots. The P as 11-52-0 was surface broadcast for the high rate (45 lb) and banded with the seed (15 lb) for the high and low rates. After wheat seeding soil samples were taken to assess P distribution for high and low P levels from fertilizer across the simulated erosion gradient which also created a calcium carbonate gradient. Wheat seedling biomass and P concentration aboveground for these areas were also assessed before the first frost.

RESULTS: Available soil P (NaHCO3-P) results showed sizable differences for both the high P fertilized soils (40 to 67 ug/g) and the low P (27 to 43 ug/g). While much variability also existed for the seedling biomass and P uptake, the high P sites showed about a 50% increase in P uptake (3.88 mg P to 2.69 mg P) over the low P sites. A difference in seedling germination was also observed because of previous weed pressures (and water removal) in the areas where no or little top soil was removed. These areas had more weeds than the high pH areas where more top soil was removed. Thus, the areas with greater top soil removed germinated about 2 weeks before those with less soil removed.

FUTURE PLANS: Phosphorus uptake in tops will be evaluated again in early April and mid May. Water content to a depth of one foot will also be monitored to evaluate the effects of the vetch cover crop. On selected areas, rooting volume and biomass to one foot will also be evaluated to see the effects of the two levels of P on root growth. Yield components (grain, stover) will also be assessed to evaluate top soil depth effects, P fertilizer effects, and vetch cover crop effects. Area should be planted to corn in 2000 which is very difficult to grow (unlike sunflower and profi peas) in our high pH calcareous soils.

AGRICULTURE AND BUSINESS MANAGEMENT ACTIVITIES IN NORTHEAST COLORADO

D.A. Kaan

COST OF PRODUCTION STUDIES: Cost of production studies have been completed for Northeastern Colorado and the Golden Plains Area counties this winter. These studies have been completed for dryland crops including winter wheat, corn, millet, and sunflowers. Irrigated crops include winter wheat, corn, dry beans, alfalfa, potatoes and sugar beets. Data collection for these studies was achieved through individual surveys with producers throughout Northeastern Colorado. Typical crop enterprises were defined for each drop based on the survey data collected. These cost of production studies will be published in the 1999 Golden Plains Area Agricultural Handbook.

RISK MANAGEMENT EDUCATION: Risk management education under funding received from USDA and CSREES is on going in Colorado. On a regional basis, Montana, Wyoming and Colorado have teamed together and pooled these seed money allocations to each state to increase the effectiveness of programming efforts. Currently, a needs assessment survey is set to go out in January to producers in Colorado and Wyoming. Montana has recently conducted such a survey and so duplication of effort was avoided. The survey data will be analyzed and educational programs will be developed based on the results. Program materials will be developed that each of the states can access and use in their programming efforts.

CONTROL OF RUSSIAN WHEAT APHID IN SPRING WHEAT
LEWTON FARM, AKRON, CO

M. Koch, S. Pilcher[1], D. Kennedy[1], M. Seward[1], J. Pilcher[1], S. Walter[2]

PROBLEM: Insecticidal treatments used to control Russian wheat aphids, *Diuraphis noxia* (Mordvilko), have not been considered satisfactory in the control of subterranean pests. Lambda-cyhalothrin (Warrior) has been proven to give excellent control of underground pests. Thus, good control of Russian wheat aphids with Warrior would be beneficial in giving added control of cutworms.

DISCUSSION: Sharp spring wheat was planted 24 March, 1998 in the field location of SW ¼, Section 15, T1N, R51W, Washington county, Colorado. Soil type is a Platner Orego loam. Treatments were applied on 18 May 1998 with a CO_2-powered A002-TX Spray System sprayer calibrated to apply 10 gal/acre through TX 6 nozzles mounted on a 4 ft boom. South winds were approximately 3 mph and temperature was 20°C. Plots were 4 ft by 25 ft and were arranged in four replicates of a randomized complete block design. Crop stage at application was stem elongation (Zadoks 33). Each plot was infested with 270 Russian wheat aphids per one yard of drill row on 18 May 1998.

Treatments were evaluated by collecting all the tillers in one foot of the infested drill row at 7, 14 and 20 days after application. Tiller samples were placed in Berlese funnels for 24 hours to extract aphids into alcohol for counting. Aphid counts transformed by the square root method were used for ANOVA and mean separation by the Student-Newman-Keul test (α=0.05). Original means are presented in the table. Reductions in insect days were calculated by Abbott's (1925) formula: (percent reduction = ((untreated-treated)/untreated) X 100).

Aphid pressure was severe. The Warrior treatment gave control equivalent to the commercial standard, Lorsban, at 1, 2 and 3 weeks after treatment. There were no differences among treatments in terms of reduced aphid days. No phytotoxicity was observed with any treatment.

PRODUCT LB (AI)/ACRE	APHIDS PER 10 TILLERS ± SEM[1] 1 WEEK	2 WEEKS	3 WEEKS	TOTAL APHID DAYS	%REDUCTION[2]
WARRIOR, 0.01	16 ± 8 A	49 ± 19 A	52 ± 22 A	580 ± 155	96
LORSBAN, 0.50	1 ± 1 A	22 ± 9 A	22 ± 8 A	233 ± 77	98
CONTROL	177 ± 79 B	823 ± 293 B	1891 ± 850 B	12996 ± 5255	---
F Value	18.35	10.29	11.22	5.62	---
p > F	0.0028	0.0115	0.0094	0.0421	---

[1]SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK (α=0.05).
[2]Percent reduction in total aphid days, calculated by the Ruppel method.

FUTURE PLANS: As new products are released for use on wheat crops, they will be tested for potential benefits not expressed in the label.

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[2]Department of Bioagricultural Sciences and Pest Management

COLLABORATIVE ON-FARM VARIETY TESTING FOR RUSSIAN WHEAT APHID RESISTANCE

M. Koch

PROBLEM: This study is a side-by-side comparison of TAM107 as the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), susceptible variety with three resistant varieties. The resistant varieties were Yuma, Prowers and Halt. Phosphorus was added to half of each strip according to soil test results. This was done to compare insect infestations into plots which were fertilized to obtain maximum yields versus the common economic yields sought by farmers.

APPROACH: The plot was located 2.5 miles north and one mile east of Platner, Colorado. The soil type was a Manter-Julesburg sandy loam. Each plot was fifteen feet wide and 1352 feet long. Soil tests showed the initial phosphorus level at 14.85 pounds per acre using a Beckman DV-600 analyzer. Ten pounds of actual phosphorus was applied at planting. The phosphorus was applied with the seed. All plots were planted with a John Deere 750 Drill. Row spacing was 7.5 inches. A slightly greener and heathier appearance was noticed in the fertilized strips throughout the growing season. There were no major insect problems at this site.

Harvest was conducted using a John Deere 9400 combine. Total weight of each strip was taken with a weigh wagon. Moisture and test weights were taken and yield adjusted to 12 percent moisture.

RESULTS: Yields were reduced by a hail storm on June 22 which damaged approximately 60 percent of the crop. All varieties showed similar yield increases by the addition of phosphorus fertilizer. The average increase in yields was 16.5 percent. The highest yielding variety was Prowers with a non-fertilized yield of 18.77 bushels per acre and a fertilized yield of 22.38 bushels per acre. The lowest yielding variety was Halt with a yield of 16.27 on the non-fertilized and 20.20 on the fertilized.

No significant difference was observed in this trial while comparing yields. A year of greater Russian wheat aphid pressure would probably show significant differences with the yields and test weights being better in the resistant varieties.

FUTURE PLANS: There are no current plans for this study to be continued in the immediate area around Akron. Sites throughout the state of Colorado will continue to provide information as to the effectiveness and economics of growing resistant wheat.

ECONOMIC INJURY LEVEL OF RESISTANT AND SUSCEPTIBLE WINTER WHEAT VARIETIES TO RUSSIAN WHEAT APHIDS

M. Koch

PROBLEM: Russian wheat aphid, *Diuraphis noxia* (Mordvilko), resistant hard red winter wheat varieties have been introduced successfully in many Colorado counties. The actual resistant genes in each variety are constantly being changed. The experiment conducted in 1998 compared TAM 107, TAM107 R3, and two advanced lines being called Dn5 and Dn6 for actual tolerance to this aphid species.

DISCUSSION: The location of the plots near Akron, Colorado was at the Central Great Plains Research Station. Soil is a Weld silt loam with a rotational history of wheat-sunflower-fallow. Plot size was six feet by six feet planted on twelve inch centers. The center two rows of each plot were paired for destructive sampling and yield. The plots were infested with Russian wheat aphids (RWA) using the bazooka method on April 9, 1998. The three infestation levels were: no aphids, 60.0 RWA per row meter, and 121.6 RWA per row meter.

Destructive sampling of the row meter was done according to growth stages. The first half was sampled when Zadoks growth stage 30 was established by all plots. Actual growth stages of each plot varied from Zadoks 30 to 32. All samples were taken out of the field on May 5 and RWA numbers were beginning to increase. Total number of tillers were taken and broken into four categories: no symptoms and no RWA, no symptoms with RWA, symptomatic with no RWA, and symptomatic with RWA present. Samples were counted and immediately placed in Berlese funnels for 24 hours. The total numbers of RWA were then counted from each sample. The second half of the meter was destructively sampled to Zadoks growth stage 50 as an average. Actual growth stages for this sampling date of May 18 was 47-50. Data was collected precisely as the first sample date.

Harvesting of the experiment was done by hand and all heads in the harvest row were counted and placed in small brown paper bags. Thrashing began on August 3 using an Agriculex SPT-1 separating machine. When completed thrashing, all samples were cleaned using a small Rapsco aspirator. Now total seed weight was taken to the nearest hundredth of a gram. A sub sample of one thousand seeds was counted using a model 850-2 seed counter manufactured by The Old Mill Company. This sub sample was weighed to determine test weight. All data analysis for this study is being completed by Dr. Frank Peairs of the Bioagricultural Sciences and Pest Management Department at Colorado State University, Fort Collins, Colorado. Final results will be available in a Colorado Field Crop Insect Management Research and Demonstration Trials Technical Bulletin this spring.

FUTURE PLANS: This experiment will be continued for the 1999 growing season.

UNDERSTANDING AND MANAGING RUST, PHOMA, AND SPOTTED SUNFLOWER STEM WEEVIL IN HIGH PLAINS SUNFLOWERS

M. Koch

PROBLEM: Cultivated sunflowers *Helianthus annus* L. have become a major rotational crop in the Central great plains region. Research this year was conducted in four locations. They were: Sidney, Nebraska; Colby, Kansas; Goodland, Kansas and Akron, Colorado. The focus of the experiment was to evaluate the impact of Red rust *Puccinia helianthi*, Spotted sunflower stem weevil *Cylindrocopturus adspersus* (Leconte), and Phoma black stem *Phoma macdonaldii* on sunflower crops.

APPROACH: Plots located at the Central Great Plains Research Station were planted May 18 to maximize the stem weevil infestations. There were ten treatments replicated four times in each of two hybrids. The two hybrids selected were Sigco 964 (confection) and Cargill 187 (oilseed). Each hybrid was chosen by maturity date and similar resistance to the diseases in question.

Timing of insecticide and fungicide applications is critical to the effectiveness of each chemical. Carbofuran (Furadan 4F) was applied at planting using an FMC micro injection unit. The rate used was 24 ounces per one thousand square feet of row. Foliar treatments were made to control sunflower stem weevil with Esfenvalerate (Asana XL) at 0.05 pound active ingredient per acre. The Asana was applied to the plots using a hand-held boom sprayer made by R & D Sprayers. This was done at the eight-leaf stage of development. At the time of application, infestation was just over the economic level of one weevil per three plants.

Rust spores were inoculated into the checks and the plots to be treated with fungicides. At this time (July 28) there was no visible rust in the plots. Rust spores were applied with a spinning disc applicator. Fungicides used to control the rust spores were Tebuconazole (Folicur 3.6 F) at 7.2 ounces per acre and Propiconazole (Tilt) at 4 ounces per acre. The first Folicur treatment was applied on July 30 at the R3 growth stage. The second application of Folicur and the application of Tilt was done August 7 at the R5.1 growth stage. Phoma treatments using 5.0 ounces per acre of the new product Vanguard were done at the same time.

RESULTS: Rust and phoma ratings were made on September 2 and October 6 using visual observation as the means of rating each disease. There was no phoma in this year's study. Rust ratings are being analyzed by Dr. Tom Gulya of the Northern Crop Science Laboratory in Fargo, North Dakota.

Harvest was done by hand on 17.5 feet of row in the center two rows of each plot. The sample area was 0.002 acres per plot. Thrashing was completed by running the heads through a Wintersteiger small plot combine. Each sample was then cleaned by an aspirator and weighed to get the yield. Five stalks from each plot were sent to the lab in Fargo for dissection. The number of stem weevil larvae in each stalk will be counted. Also, lodging notes were taken prior to harvest to assess weevil damage. Samples of the seed from each plot will be analyzed for oil content and seed size. Dr. Larry Charlet of Fargo will do all of the data management for the insect part of this study. Final results will be available upon request this spring.

FUTURE PLANS: There are no plans to continue this study at the Akron location.

CONTROL OF SUNFLOWER STEM WEEVIL WITH AT-PLANT AND CULTIVATION TREATMENTS

S. Pilcher[1], R. Meyer[1], D. Kennedy[1], M. Seward[1], M. Koch, S. Walter[2], F. Peairs[2]

PROBLEM: Control of the Spotted sunflower stem weevil, *Cylindrocopturus adspersus* (Leconte), with at-plant treatments is preventative. Weather conditions play an important role in the emergence of this pest. Waiting until there is a definite problem with the weevil could save many farmers money.

DISCUSSION: The plots were planted 18 May at the Central Great Plains Research Station near Akron, Colorado. Planting time treatments were applied on 18 May 1998 with a John Deere Maxi-Merge planter equipped with a micro-injection unit. Furadan 4F at 1.4 oz per 1000 ft of drill row was diluted 1:1 with water and injected in-furrow above the seed and ahead of the press wheel. Cultivation treatments were applied on 6 July 1998 at the V6 to V10 plant growth stage with a CO_2 powered sprayer with an over-whorl nozzle (11004VS-TJ) positioned 12 inches over the whorl mounted on a Liliston cultivator. The sprayer was calibrated to deliver 10 ml/sec. Plots were four rows by 50 ft and were arranged in four replicates of a randomized complete block design. Adult weevil counts prior to the cultivation applications averaged one weevil per three plants. Treatments were evaluated on 11 September 1998 by splitting the stalks of three plants per plot and counting the number of sunflower stem weevil larvae. Percent lodging was determined on 20 October 1998 by counting the total number of plants and the number of lodged plants in the center two rows if each plot. Larval counts and lodging were analyzed for variance and mean separation by the Student-Neuman-Keul method (α=0.05).

Yields were determined by harvesting 17.5 ft of row from the center of the untreated plots and each plot treated with Furadan 4F at planting. Harvested grain was weighed and moisture and test weights were determined. Yields were converted to lb/acre. All treatments reduced weevil density. Yields were not significantly affected (two-tailed t-test, assumed equal variance, t=1.2149, df=14, $p(t>t_{.05})=0.2445$) by treatment in this experiment. The average treated yield was 767 ± 69 lb/acre while the average for the untreated plots was 651 ± 66 lb/acre.

The economic injury level for this pest based on larvae per plant is not clear. Stalk diameter and Phoma black stem also adversely affect lodging. Stalk diameter was reduced by moisture stress. However, weevil densities were also low so treatment did not reduce lodging. Phoma black stem was not a significant factor in this study.

PRODUCT, LB(AI/ACRE)	TIMING	SSW LARVAE[1]	% CONTROL	% LODGING[1]
FURADAN 4F, 0.50	CULTIVATION	0.0 ± 0.0 C	100	2.0
FURADAN 4F, 1.00	CULTIVATION	0.0 ± 0.0 C	100	2.4
FURADAN 4F, 0.75	AT-PLANT	0.2 ± 0.2 C	96	1.9
WARRIOR 1E, 0.03	CULTIVATION	0.9 ± 0.5 BC	79	7.4
TD-2344-02 8E, 0.025	CULTIVATION	1.7 ± 0.6 BC	61	9.9
WARRIOR 1E, 0.02	CULTIVATION	1.8 ± 0.7 BC	60	7.7
TD-2344-02 8E, 0.04	CULTIVATION	2.6 ± 0.7 B	40	6.8
UNTREATED	—	4.4 ± 0.7 A	0	10.0
F Value		8.59	—	1.93
p>F		< 0.0001	—	0.1112

[1]Sunflower stem weevil larvae per three plants. Means in the same column followed by the same letter(s) are not statistically different, SNK (α=0.05).

FUTURE PLANS: This experiment will be conducted once again for the 1999 growing season.

[1]Golden Plains Area Cooperative Extension
[2]Department of Bioagricultural Sciences and Pest Management

CONTROL OF SUNFLOWER INSECTS WITH AERIALLY-APPLIED INSECTICIDES

S. Pilcher[1], D. Kennedy[1], M. Seward[1], M. Koch, S. Walter[2], F. Peairs[2]

PROBLEM: Cultivated sunflower production in Colorado has increased significantly over the past decade. With the increase of production, comes an increase in the pest potential of a crop. This study will help provide answers to the effectiveness of chemicals on the Banded sunflower head moth, Cochylis hospes (Walsingham), and seed weevils, *Smicronyx* spp., when treated by an airplane.

DISCUSSION: Plot location was the Central Great Plains Research Station near Akron, Colorado. The variety used was Cargill 187 with a planting date of 20 May. Treatments were applied on 2 August 1998 with a Weatherly 802B aircraft equipped with 32 CP nozzles (deflectors set at 125°) on a 42 ft boom, calibrated to apply 2 gal/acre at 20 psi and an air speed of 125 mph over an effective swath width of 60 feet. Conditions at the time of treatment were temperature 84°F, relative humidity 52% and wind speed less than 5 mph. Plots were 180 ft through the 4.2 acre field. The treatments were applied when 5 to 10% of the plants were in the R-5.1 (early bloom) plant growth stage.

On 19 August twelve heads in the R-6 plant growth stage (wilted ray petals) were selected per plot and covered with Delnet bags, each containing one cup of soil. Bagged heads were collected at the R-8 growth stage (onset of physiological maturity). Treatments were evaluated on 27 October by counting banded sunflower moth larvae in the heads and seed weevil larvae in the soil. Data from treated plots were compared to the untreated control using a two-tailed t-test with assumed equal variance (α=0.05).

Red seed weevil adults averaged 4.0 per head and Gray seed weevil adults averaged 0.5 per head prior to treatment. Sunflower moth and Banded sunflower moth were monitored with pheromone jug traps.Banded sunflower moths averaged 7 moths per trap per night at the time of treatment. No Sunflower moths were detected through the monitoring period.

All treatments controlled seed weevils (Table 1). Both rates of TD2344-02 controlled banded sunflower moth although both trap catches and larval densities were below economically significant levels. No phytotoxicity was observed with any treatment.

PRODUCT, LB(AI)/ACRE	LARVAE PER HEAD		% CONTROL SEED WEEVILS
	BSM[1]	SEED WEEVILS[1]	
TD 2344-02 0.8E, 0.025	0.0 ± 0.0 (0.0063)	0.3 ± 0.1 (0.0009)	99
WARRIOR 1E, 0.03	0.3 ± 0.2 (0.2191)	0.7 ± 0.6 (0.0011)	97
TD 2344-02 0.8E, 0.04	0.1 ± 0.1 (0.0265)	0.8 ± 0.4 (0.0011)	97
LORSBAN 4E, 0.75	0.2 ± 0.1(0.0755)	1.5 ± 0.7 (0.0015)	94
UNTREATED CONTROL	0.6 ± 0.2	24.4 ± 6.3	---

[1]Number in parenthesis is the probability of being similar to the untreated control, calculated with a two-tailed t-test with assumed equal variance (α=0.05).

FUTURE PLANS: It is expected to continue this experiment in 1999 to evaluate the effectiveness of new chemicals as well as those used in the test this year.

[1]Golden Plains Area Cooperative Extension
[2]Department of Bioagricultural Sciences and Pest Management

DETERMINING THE AFFECTS DRYLAND CROPPING ROTATIONS HAVE ON INSECT POPULATIONS

M. Koch

PROBLEM: The trend towards increasing land production through cropping intensity has brought many new challenges face-to-face with the farmer. Management of available resources to obtain maximum economic yields from a parcel of land is becoming more difficult with the introduction of new cropping rotations. The focus of this study is to examine the affects of the new systems on insects.

DISCUSSION: The dry weather conditions for the first two years of this study have produced challenges not anticipated. Weeds will be a much greater concern for overall crop production than first thought. Thus, herbicide and tillage usage will be a primary issue in the future.

Wheat plots did not have insect problems this year. The wheat yields ranged from 11 to 42 bushels per acre. The lack of rainfall contributed highly to the spread in yields. Wheat-corn-millet rotation plots averaged 12.66 bushels for TAM 107 and 12.53 for the Halt variety. Compare these averages to the 32.07 bushels per acre average of the other rotations which have a fallow period.

Corn harvest showed good yields considering the history of the plots. Several of which have had four continuous crops prior to this year. An average yield of more than 43 bushels per acre with a test weight of 56.4 was considerably better than expected.

Sunflowers did not fare well this year. The yield of 682.45 pounds per acre did not cover input costs. Test weights were good at 26.03 pounds. Insects did not reach economic levels in either crop.

Millet plots for 1998 were completely lost. A combination of drought and weed pressure caused the plots to be destroyed. Swathing and baling of these areas removed much of the weed seed. Allowing the weeds to mature during the growing season used enough water to simulate the crop being produced. Next year the weather may be a little better and get the millet crops back into production.

FUTURE PLANS: As the plots get established and the rotational affects become more pronounced, a greater amount of data will be taken from the plots. This is a long-term project which will eventually help producers identify the positives and negatives of common rotations in the area. Few studies have tried to include all aspects of rotations to arrive at the same goal. To achieve the goal of determining the affects of the rotations on insects, cooperation with variety testing programs, agronomy and weed science staff, and entomologists is imperative.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

D.C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. The objectives of this experiment were to determine best adapted cultivars and optimum plant populations for alternative crop species.

APPROACH: Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review. During the 1998 growing season, four chickpea (garbanzo bean) cultivars (three kabuli and one desi type), one lentil cultivar, and six pea cultivars were evaluated, each at two seeding rates. The two seeding rates for chickpea and lentil were higher and lower than recommended rates from other sources. All plots were planted on 10 April with 10 in. row spacing for chickpea and lentil, and 15 in. row spacing for pea.

RESULTS:

Crop	Variety	Type	Population lbs/acre	Yield lb/acre	Crop	Variety	Population lbs/acre	Yield lb/acre
Chickpea	UC5	Kabuli	150	246	Pea	Integra	60	340
Chickpea	UC5	Kabuli	75	232	Pea	Integra	120	728
Chickpea	UC27	Kabuli	125	347	Pea	Profi	60	447
Chickpea	UC27	Kabuli	63	218	Pea	Profi	120	723
Chickpea	Tammany	Kabuli	181	160	Pea	Majoret	60	396
Chickpea	Tammany	Kabuli	91	116	Pea	Majoret	120	606
Chickpea	Sanford	Kabuli	137	224	Pea	Atomic	60	334
Chickpea	Sanford	Kabuli	68	171	Pea	Atomic	120	545
Chickpea	Myles	Desi	75	561	Pea	Alfetta	60	427
Chickpea	Myles	Desi	38	438	Pea	Alfetta	120	590
Lentil	Brewer		174	409	Pea	Highlight	60	241
Lentil	Brewer		87	398	Pea	Highlight	120	529

INTERPRETATION: Very dry conditions (less than 30% of normal precipitation) for April, May, and June resulted in poor stands and very low yields of all crops tested. The desi type chickpea again showed greater yield under drought conditions than the kabuli types. All pea varieties showed a positive yield response to increasing plant population.

FUTURE PLANS: The experiment will be conducted similarly next year. Pea seeding rate will be increased to the recommended rate of 180-200 lb/a.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

D.C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield.

APPROACH: Crops tested during the 1998 growing season were peas (Profi, planted April 6), garbanzo beans (UC5, planted April 10), lentils (Brewer, planted April 10), cowpeas (Peregrin northern brown-eye, planted May 19), pinto beans (Fisher, planted May 28), and foxtail millet (Golden German, planted June 11). The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses and the lowest level being rainfed with no supplemental irrigation. Soil water measurements were made with a neutron probe. Water use was computed by the water balance method. Garbanzo bean, lentil, and millet plots were abandoned due to poor stands, herbicide failure, and intense weed pressure. Profi peas were harvested on July 2. Pinto beans were harvest on Sept. 4 and 10. Cowpeas were harvested on Sept. 8.

RESULTS: Cowpea stands were poor, and only a small area was maintained to provide seed increase for next year. Pea yield ranged from 450 to 1350 lb/a over an ET range of 6.7 to 11.5 in. Pinto bean yield ranged from 1100 to 2500 lb/a over an ET range of 10.5 to 17.1 in. Yield increased linearly with increased water use.

INTERPRETATION: Pinto bean yield in the dryland plot area (receiving only 6.6 in. rainfall during the growing season) averaged 1521 lb/a, making it a viable alternative crop if low residue and tillage/harvest concerns can be overcome. Pea yields may improve as we push the seeding rate up (180 lb/a recommended vs 120 lb/a used in 1998).

FUTURE PLANS: Garbanzo bean, lentil, and pinto bean results will be submitted for publication. Work will continue with foxtail millet, profi pea, and another garbanzo bean (desi type).

KENAF WATER USE AND PRODUCTION (FORAGE AND FIBER) UNDER A RANGE OF WATER AVAILABILITY

D.C. Nielsen

PROBLEM: Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield. Kenaf is a potential alternative crop that has both fiber (paper, building materials, absorbants) and forage (livestock feed) uses.

APPROACH: Two experiments were conducted with kenaf (Everglades 41). A solid set, gradient irrigation area was planted May 5. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses and the lowest level being rainfed with no supplemental irrigation. In the second experiment kenaf was planted under a rainout shelter on May 8. Water treatments were 33, 67, 100, and 133% replacement of ET loss each week. Soil water measurements were made with a neutron probe. Water use was computed by the water balance method. One area of solid set kenaf was cut for yield and forage analysis on Aug. 12, allowed to regrow, and harvested again on Oct. 13. Samples of the first and second kenaf harvests were ensiled in mini-silos. A second area of kenaf grown for fiber grew from planting to Oct. 15. Rainout shelter kenaf was harvested for yield and forage analysis on Aug. 3. Iron chelate was misapplied to the regrowth at 10 times the recommended rate on 2 Sept. causing death of plants and termination of this part of the experiment.

RESULTS: Forage production of kenaf was related to water use. Total dry matter produced for the two solid set cuttings ranged from 2500 to 4000 lb/a over an ET range of 13 to 18 in. Forage characteristics are given in the following table.

Location	Cutting	% Crude Protein	% NDF	%ADF	Relative Feed Value
Gradient	1st	17-21	34-41	26-28	150-190
Gradient	2nd	AA	AA	AA	AA
Gradient	1st, Silage	18-20	37-53	34-33	112-172
Shelter	1st	17-20	38-43	30-32	139-162
Shelter	2nd	NA	NA	NA	NA

(AA=Awaiting Analysis, NA=Not Available) We noted higher fiber, lower crude protein, and lower relative feed value than in 1997(but still high).Crude protein and relative feed value tended to decrease with increasing water use. NDF and ADF tended to increase with increasing water use.

INTERPRETATION: Kenaf produces a high quality forage, but low yields compared with corn and forage millet do not favor it for a dryland livestock forage in this area.

FUTURE PLANS: Both kenaf experiments will be repeated next year. A side-by-side comparison with corn silage will be conducted.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

D.C. Nielsen, R.L. Anderson, R.M. Aiken, M.F. Vigil, R.A. Bowman, and J.G. Benjamin

PROBLEM: Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Information is needed regarding water use patterns, rooting depth, water use/yield relationships, precipitation storage and use efficiencies, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains.

APPROACH: Six rotations [W-F(CT), W-C-F(NT), W-C-PEA(RT), W-SUN-F(RT), W-M-SUN-F(RT), W-SUN-M-PEA(RT)] are used for intensive measurements of water use and water stress effects on yield. (W:winter wheat, C:corn, F:fallow, M:proso millet, SUN:sunflower, PEA:pea CT:conventional till, RT:reduced till, NT:no till). Measurements include soil water content, plant height, leaf area index, grain yield, residue mass and cover, and precipitation.

RESULTS:

Rotation	Crop	ET (in)	Yield (lb/a)	Rotation	Crop	ET (in)	Yield (lb/a)
W-F(CT)	wheat	10.6	1937	W-C-PEA(RT)	corn	10.3	1937
W-C-F(NT)	wheat	13.9	2193	W-C-F(RT)	corn	11.2	2956
W-C-PEA(RT)	wheat	8.5	688	W-SUN-F(RT)	sunflower	11.4	700
W-SUN-F(RT)	wheat	9.1	1067	W-M-SUN-F(RT)	sunflower	11.1	1533
W-M-SUN-F(RT)	wheat	9.3	1181	W-SUN-M-PEA(RT)	sunflower	13.1	1406
W-SUN-M-PEA(RT)	wheat	8.8	711	W-M-SUN-F(RT)	millet	7.9	2017
W-SUN-M-PEA(RT)	pea	4.5	257	W-SUN-M-PEA(RT)	millet	6.1	1885
W-C-PEA(RT)	pea	5.2	288				

INTERPRETATION: Very dry conditions (less than 30% of normal precipitation) for April, May, and June combined with greater than 30% higher precipitation in July and August resulted in higher yields for corn, sunflower, and millet than predicted by previously established yield/water use relationships. As in 1997, wheat yields were much higher than expected for the measured amount of water use (no explanation currently developed.)

FUTURE PLANS: Water use, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made for as long as these rotations exist. An analysis of fallow season precipitation storage efficiency by residue type, rotation, and time of precipitation will be written for journal publication this year.

TRAINING NRCS FIELD OFFICE EMPLOYEES TO A PROFICIENT KNOWLEDGE LEVEL OF SOIL QUALITY RELATED TOPICS

M. Sucik, J. Saunders, M. Rosales

PROBLEM: Since the onset of the Food Security Act of 1985, many Natural Resource Conservation Service employees have not received adequate training in technical areas of soil science and soil quality. The agency has been inundated with programs such as CRP, EQIP and conservation compliance issues and has needed to administer this increased workload, often with a reduced staff and budget. The agency is looked at by many as the leader in providing technical soil and other natural resource information to the public it serves. Many experienced technical leaders have retired and the agency does not have any formal training available to offer younger, less experienced employees in the area of soil quality.

APPROACH: The NRCS Soil Quality Institute with assistance from the Northern Plains Region Soil Quality Team submitted a proposal to the NRCS National Employee Development Staff to design and develop a formal training course that would enhance all NRCS employees knowledge of soil quality, soil physical, chemical, and biological properties and the effect that management practices have on the soil resource. The course would also teach participants to measure soil properties in the field ensuring that employees can spend more time in the field working with customers.

RESULTS: In August of 1998, a design team met at Fort Worth, Texas to design the proposed course entitled: "Soil Quality - Assessment and Applications for Field Staff". The design team suggested seven different lessons in the area of soil quality that would compromise approximately a one week training course. The lessons are: Soil Quality Background, Soil Properties/Indicators, Documentation and Measurement, Interpretation, Impacts/Effects of Management, Soil Quality Outreach, and Soil Quality and Conservation Planning. The design of the course was approved by the employee development board and an instructor cadre was established to develop and deliver the course. The cadre met in December to develop the lessons and plan a timetable for delivery. Each member of the team was assigned responsibilities to ensure the course is delivered on schedule.

FUTURE PLANS: The development team will meet in February of 1999 to finalize the contents of the course. In May, 1999, the team will go through a dress rehearsal of the course to make sure all items have been addressed. In August, the course will be piloted at Colorado Springs, Colorado with employees attending from all parts of the country. The participants will give feedback to the effectiveness and usefulness of the course and its applicability to day to day operations. The development team will incorporate this feedback into the courses finished product. The training will then be delivered to participants in each region of the country. Participants will then be expected to see that all or most employees in their region of the country receive this training.

INFLUENCE OF LEGUME GREEN-MANURE ON WINTER WHEAT YIELDS

M.F. Vigil, D.C. Nielsen, R.A. Bowman

PROBLEM: With the exception of water, nitrogen (N) nutrition is the most important limiting input to profitable winter wheat production in the central Great Plains. Increases in N fertilizer costs have caused some farmers to consider alternative systems that include legumes as a source of N. Farmers need to know how these systems impact winter wheat yields and economic returns.

APPROACH: Two sites have been established in which the main plots consist of legume species: Austrian winter peas, spring field pea (cv. Profi), Hairy Vetch and a no-legume-summer-fallow plot fertilized at four N rates 0, 30, 60, and 90 lb N/ac. Within each main-plot, four sub strip plots are maintained which consist of four legume growth termination dates spaced two weeks apart. Soil water is measured in all legume plots and in the fallow plots at legume planting in April, at each legume-growth-termination event, at wheat planting and at wheat harvest to determine water used by the legume and the wheat. Above ground N and total legume biomass is determined at each termination date. Soil inorganic N is measured in each plot at each termination date in the top 2 feet of soil and at wheat planting time to monitor changes in available N. Following the legume fallow phase, wheat is planted and harvested using standard BMP's for dryland winter wheat.

RESULTS: We have three years of legume biomass data, and three years of winter wheat yield data. Austrian Winter peas (AWP) have been the overall best performer as measured by biomass production (between 1500-3000 lbs biomass/acre) and total above ground N in plant tissue (50-130 lbs N/acre). For the AWP we calculated a water-use efficiency of 335 lbs of dry matter per inch of water used on June 13, 1994. The 335 lbs of biomass, contained 11.6 lb of N. In other words, 11.6 lbs of N was fixed or taken up by the legume for each inch of water use. The legumes used 5 inches of water (in addition to that amount lost in summer fallow) to produce 2400 lbs of dry matter. That 5 inches of water use has the potential of producing 25-30 bushels of wheat. We measured reductions in wheat grain yields all three years. Eighty-eight percent of the variability in wheat yield loss could be described by a equation based on the previous year's legume water use (ET). At current fertilizer costs legume N is too expensive to be considered a reasonable alternative to chemical fertilizer in this system. In wet years the value of the forage ($80/ton) plus the wheat yield grown the subsequent year will bring higher net returns than wheat fallow. In a dry year the reverse is true and no legume should be grown during summer fallow.

FUTURE PLANS: We are continuing the experiment for another three seasons We believe that six complete cycles of the system are needed to make a fair evaluation of potential changes in soil organic matter and mineralizable N. A first manuscript will be published in the November -December issue of Agronomy Journal, 1998.

NITROGEN MINERALIZATION FROM MANURES AND MUNICIPAL SEWAGE SLUDGE

M.F. Vigil, G. Smith, B. Jakubowski, J. Davis, B. Eghbal, R.A. Bowman

PROBLEM: The disposal of animal waste and municipal sewage sludge from large population centers and concentrated animal feeding units is an environmental concern. These materials, loaded with organic and inorganic nutrients, can be recycled in crop production systems as fertilizer and soil quality amendments. If managed properly, they become a resource instead of waste. However, the quantification of suitable rates of application, methods of application, crop response, and changes in soils after repeated application are data needed to adequately develop best management practices (BMP's) for these amendments.

APPROACH: The objectives of these experiments are to determine: the amount and rate of decomposition of organic amendments (manures and sewage sludge) in farm soils, as fertilizer and as soil quality amendments for crop production.

Lab studies are being conducted on 20 select animal manures representing 7 animal species. N mineralization (N_{min}) and C mineralization (C_{min}) are being measured in manure-amended central Great Plains soils to developed first-order-decay-rate constants for these materials. Simultaneously we are evaluating computer models for their ability to predict how these amendments will impact soil nutrient availability and crop uptake. Field studies with the resin-bag In-situ N_{min} method will begin May of 1999.

RESULTS: Rates of N_{min} for 20 animal manures ranged from net immobilization (0 N_{min}) to 70% of the applied N being released after 132 days of incubation at optimum temperature and near optimal soil water contents.

We estimate from our lab studies that dry-granulated sewage sludge (5.3% N) applied at rates of 1.5 ton and 9 ton per acre will release (through microbial decomposition) 45 and 270 lbs of N in a given season under irrigated conditions in our region (about 28% of the total N applied). Under dryland conditions we may only see 34 to 200 lbs of N released for 1.5 and 9 tons of dry sludge. Less sludge N mineralization is expected on dryland because dryland soils are less biologically active then moist irrigated soils.

FUTURE PLANS: Lab studies are only in the beginning phases of research and will be continued. We are evaluating these products as an amendments to reclaim eroded soils. The Modeling effort is slowly moving along.

FIFTEEN YEARS OF DRYLAND CROPPING WITHOUT SUMMER FALLOW

M.F. Vigil, R.A. Bowman

PROBLEM: Conservation tillage has increased annual soil water storage. This has enabled the use of annual cropping for some soils of the central Great Plains. Annual cropping entails greater biomass production which increases surface crop residues impacting soil quality and soil water storage efficiency. This study is designed to evaluate long term changes in soil C and N under annually cropped dryland conditions under different N fertility. Short term, the study allows for the estimation of N use efficiency and fertilizer N requirements of various dryland crops.

APPROACH: This is the 15th year of the experiment, where under dryland conditions, the site has been cropped successfully with no fallow on a Weld silt loam. The site was a barley-corn rotation until 1992 when oats for hay replaced spring barley. We have had two failures in the 15 years of cropping: winter wheat was grown in 1988 to replace a hailed out corn crop in 1987 and in 1990, poor stand and aphids limited barley yields to 21 bu/acre. The experiment is a 4-rep randomized complete block where the only treatment is N fertilizer rates of 0, 20, 40, 60, 80 or 120 lb N/acre. The study is managed with no-till to conserve water, and weed control has been through the use of contact and residual herbicides. Phosphorous (P) nutrition has not been limiting but low rates of P have been applied with the seed at planting or as broadcast treatments. Soil profile water and nitrates are monitored annually to determine N balance and water use efficiency.

RESULTS: Through the years, the optimum N rate for the grain crops has been between 40 and 60 lbs N/acre for wheat and between 60 and 80 lbs for corn. A buildup of excess nitrate-N can be found in the soil of plots fertilized at 80 lbs or more. These results suggest that with this soil (under dryland conditions) annual fertilizer N rates greater than 80lb/acre, are excessive for the crops and management currently available.

Triticale yields in 1995 were 5.5 ton/acre at an optimal N rate of 80 lb/acre. In 1996, maximum corn grain yields of 90 bu/acre were measured at the 120 lb N rate. At the 80 lb N rate 75 bu/acre of grain was harvested. In 1997, the unfertilized profi-pea crop got off to a slow start with a dryer than normal April. However, on 11, July 1997 we harvested 900 to 1100 lbs of grain with a whole plot average of 1011 lbs/acre. The 1998 crop of winter wheat averaged 26 bushels in the fertilized plots and 22 bushels in unfertilized plots.

FUTURE PLANS: The crops for the next three years will be corn, then sunflowers and then either roundup ready soybeans, dry edible beans or millet. The fourth year we will plant winter wheat. The experiment will continue for another 4 years to evaluate long term soil changes under high N management and to determine changes in soil C and N with high productivity. We are using ^{15}N in some of the plots to evaluate fertilizer N recovery.

NITROGEN RESPONSE AND RESIDUE MANAGEMENT OF SUNFLOWERS IN A DRYLAND ROTATION

M.F. Vigil, R.A. Bowman

PROBLEM: The current worldwide demand for edible oils has improved and somewhat stabilized the profitability of sunflowers in the Central Great Plains. However, knowledge of options for sunflower residue management and the fertilizer N response of this crop in the region is limited. Maintaining sunflower residues on the soil surface during fallow protects the soil from erosion, increases water infiltration and maximizes soil water storage. The objectives of these studies are: (i) to compare the loss of sunflower residues under no-till and reduce-till managed summer fallow, and (ii) to evaluate the nitrogen (N) use efficiency and plant derived N from fertilizer of this crop in a wheat-millet-sunflower-fallow rotation.

APPROACH: Sunflower were planted and fertilized in a randomized split-plot 4-rep experiment. Main plots consist of rotation crop/phase (sunflowers, proso-millet, wheat or fallow) and sub-plots are fertilizer N rates of 0, 30, 60, or 90 lb N/acre. All phases of the rotation appear every year in each replication. Soil water and inorganic N are monitored at planting and after harvest to assess water and N use efficiency and to evaluate deep N and water extraction by sunflowers. Individual plots are 60 ft by 240 ft in size. Deep placed ^{15}N labeled N is being used to evaluate fertilizer N recovery with soil depth.

RESULTS: After four cropping seasons a small yield response has been measured in only this last year. Sunflower grain yields have averaged near 1000 lbs over the four years regardless of fertilizer application rate. That is somewhat surprising because the 0 (check) fertilizer plots have not received N fertilizer for three years. We have measured deep removal of inorganic N at the 5 foot depth. But still have not measured a yield response.

FUTURE PLANS: For both studies only two years of data has been collected. The N response of sunflowers in a rotation requires at least 2 complete cycles of the rotation for long term conclusions.

SOIL CARBON AND NITROGEN CHANGES IN A LONG TERM TILLAGE STUDY

M.F. Vigil, R.A. Bowman, R.L. Anderson

PROBLEM: Winter wheat-fallow is the dominant cropping system in the Central Great Plains region of the United States. During fallow, weeds are generally controlled using sweep-plow tillage (stubble mulch). Weed control with herbicides is generally too expensive unless a more intensive rotation is adopted. On the other hand, conventional tillage during fallow reduces soil organic matters levels at the soil surface and increases wind and water erosion.

APPROACH: This study was originally established in 1967 by Darryl Smika, and modified by Merle Vigil and R.L. Anderson in 1996. In 1967 four weed control strategies during fallow were compared. These were no-till (residual and contact herbicides only), reduce-till (residual herbicides in August after wheat harvest followed by tillage the next summer after residual herbicides had failed), stubble-mulch (sweep-plow managed summer fallow), and a moldboard plow treatment. This core set of plots has been kept since 1967. We have added a four year rotation of wheat-proso millet (or corn depending on weed and moisture conditions)-sunflower-summer fallow. This rotation was established to evaluate long term changes in soil Carbon and soil organic matter as influenced by intensive management. Other studies of an academic nature have included: a Delta ^{13}C dating of soil organic matter pools, studies to evaluate infiltration and compaction as influenced by long term tillage, and studies to evaluate fungal verses bacterial activity as influenced by tillage.

RESULTS: In general the no-till plots have not produced better than the tilled plots. The moldboard plow plots are less weedy then either the sweep tilled plots and/or the no-till or reduce till plots. The plots that have been exclusively in a wheat-fallow rotation are infested with jointed goat grass and cheat grass. Plots that have had a three year rotation of wheat-corn-fallow are relatively much cleaner with respect to weeds. Soil organic matter levels are being evaluated as a function of tillage and soil depth. The largest difference (as you might expect) is with lower surface organic matter levels in the moldboard plow treatment as compared with the no-till plots. Nearly 15 times more fungal activity is measured in the surface 15 cm of these soils than bacterial activity with no significant differences between tilled and no-till plots.

FUTURE PLANS Grassy weed pressure is so intense that we will not grow winter wheat on the land for the next 4 years. Oats or peas will be substituted for winter wheat over the next few years until we get control of the cheat and jointed goat grass problems. Because of its long term history, the experiment has become valuable for looking at long term changes in soil organic matter, total soil N and C and changes in soil tilth at the soil surface. The experiment has been identified as a unique part of a network of long term experimental sites across the United States and Canada. Long term changes in soil surface C and soil tilth are being evaluated across that site network. We would like to keep the experiment going for 8 years in order to complete 2 cycles of the four year rotation.

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